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The Clay and Shale Industries of Ontario

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Summary and Introduction

Executive Summary

All of the Ontario industries using domestic clay and shale, and imported clays, are reviewed in detail, with the exception of the clay filler industry which has been previously recorded.[1] Characteristics of the principal clay and shale raw materials are also reviewed.

Common Clays of Ontario

Once extensively used in brickmaking, and more recently for drainage tile, the common surface clays of Ontario are little used today. All are linked to the glacial history of Ontario, and reflect the compositions of Ontario's bedrock. Most are red or buff–burning calcareous illitic clays of poor ceramic quality. Small deposits of interglacial clay at Toronto, and a unique shale–derived clay at Hamilton and Burlington, had improved ceramic properties, but both have long since been depleted or lost to urbanization.

Shales of Ontario

Paleozoic shales of the Queenston, Georgian Bay and Arkona Formations are restricted to southern Ontario where they are the bases for Ontario's heavy clay products industries: bricks, drainage tiles and flue linings. It is a fortunate coincidence that the Queenston and Georgian Bay shales outcrop near Ottawa and Toronto where they are utilized for brickmaking, and while overall reserves are not yet scarce, it is essential that some shale areas be preserved for future utilization. Drill testing to confirm shale quality is recommended for areas selected for preservation.

Except for the Precambrian Rove Shale of the Thunder Bay area, which is inclined to be too brittle for ceramic purposes, shales are scarce in northern Ontario.

Kaolin Clays of Ontario

High–quality kaolin clays of Cretaceous age occur beneath heavy overburden in the Moose River Basin of northeastern Ontario. While access is difficult and their location remote, these deposits have the potential to replace large imports of high quality clay and foreign products made from such clays. A major hurdle is the cost of transporting the Moose River clays to markets in southern Ontario and elsewhere.

Except for small deposits of similar clays recently discovered during exploration for residual phosphate deposits in the nearby Cargill and Martison Lake carbonatites, where the clays have apparently been protected from glacial removal by the topography of the complexes, kaolin clays of commercial interest occur nowhere else in Ontario. A variety of refractory clays, including fireclay, ball clay and stoneware clays are interlayered with thick deposits of quartz sand containing appreciable amounts of fine white kaolin dispersed throughout the sand matrix.

Bricks

Record sales of 464 million bricks were realized in Ontario in 1985 from eight operating plants, the fewest number of brick plants ever recorded in the province. Four plants are operated by Canada Brick Co. Ltd. in the Toronto–Hamilton area, and one near Ottawa. Brampton Brick Ltd. operates two plants at Toronto and Brampton, and Hamilton Brick Ltd., one plant at Hamilton. All use shale exclusively; six plants use Queenston Shale and two use Georgian Bay Shale.

While Domtar Construction Materials Ltd. and Toronto Brick Ltd. have recently sold their brickmaking operations to Canada Brick and Brampton Brick, respectively, the industry is prosperous and healthy. However, coloured concrete bricks, which are less expensive than clay bricks, are gaining acceptance and a significant share (about 25 percent in 1985) of the residential home–building market.

Drainage Tile

The use of clay drainage tiles in Ontario is in serious decline, as it is in most parts of the world, the result of competition from plastic tubing. Five Ontario plants produced about 10 million tiles in 1985, compared with a peak production of 68 million tiles by about 30 plants in 1968. Only four plants plan to operate in 1986, two using shale, and two using clay, all in southwestern Ontario.

In 1985, three plants introduced a new 3.5–inch (9 cm) clay tile which was closely competitive in cost and performance with 4–inch (10 cm) corrugated plastic tubing. Also, an adaptation of the plough technique for laying plastic tubing for application in clay tile installation has brought down the

1. Ministry of Natural Resources, Industrial Mineral Background Paper 5, 1984.

installation cost for clay tiles nearly to that for plastic.

Hard–pressed tile producers have experimented with a variety of other clay products in an attempt to remain economically viable. Wine racks, flowerpots, roofing tiles, floor tiles, bricks, flue liners and cat litter have been tried. However, the generally inferior quality of Ontario's surface clays has defeated large–scale development of these industries, although plants using shale have had more encouraging results.

Sewer Pipe, Flue Liners

After more than a century of production in Ontario, clay sewer pipes are no longer made in significant quantity. Like clay drainage tiles, clay sewer pipes are being supplanted by a concrete product in the larger diameters and plastic pipes in the smaller sizes. Rigid plastic pipes 6 m to 9 m in length are less expensive, lighter in weight and more easily handled and installed than clay pipes. National Sewer Pipe Ltd. ceased production of clay sewer pipes at its Mississauga plant in 1981, and only 500 to 1000 tonnes of clay pipe were produced at the company's subsidiary in St. Thomas, Canada Vitrified Products Ltd., in 1985.

Clay flue liners and plastic drainage tubing were the principal products of Canada Vitrified Products Ltd. in 1985. Queenston Shale trucked from Burlington is the main raw material, and Arkona Shale was being tested as an additive in place of fireclay imported from Alfred, New York. Insulated steel pipe is a significant competitor for masonry chimney systems.

Expanded Aggregate

Concrete aggregate weighing about half as much as sand or gravel can be made by flash–firing clay or shale. Use of such aggregate in high–rise construction projects can realize significant savings, particularly in structural steel requirements. Currently shale is not being used as a raw material in the production of expanded aggregate in Ontario.

Some of the red–burning surface clays of Ontario, and some of the Paleozoic shales, show promise for the making of medium weight aggregate by the rotary kiln process. In fact, such a product, known as Haydite, was manufactured by Domtar Construction Materials Ltd. in Mississauga, using Georgian Bay Shale from 1965 to 1980. From 1928 to 1965 the Haydite product was a crushed expanded clinker which found wide acceptance, particularly in the making of lighter weight concrete blocks. Higher energy costs and environmental requirements led to the plant closure in 1980.

Expanded clay and shale aggregates compete with aggregate made from steel furnace slag which has about the same bulk density. National Slag Limited of Hamilton now produces the only expanded aggregate in Ontario.

Mineral Wool

Mineral wool competes with fibreglass for much of the residential insulation market. Mineral wool was made by four Ontario plants in 1985 using steel furnace slag as its principal raw material.

However, mineral wool can also be made from rocks of suitable composition. From 1938 to 1978 Spun Rock Wools Ltd. produced "rock wool" from dolomitic Rochester Shale at its plant in Thorold. Actually, many Ontario shales, mixed with suitable proportions of dolomite, could be so used. However, where slag is readily available and of consistent composition, it is preferred over natural raw materials.

Floor and Wall Tile

Ceramic floor and wall tiles are enjoying a high level of consumer demand in North America after many years of relative disinterest. Per capita consumption in Italy, for example, is five times that in Canada and ten times that of the U.S.A. Estimated Canadian consumption in 1985 was 12 million m^2, of which more than 90 percent was imported.

However, 1985 was an important year for floor and wall tile in Ontario. While several older plants had been closed in recent years, two were being renovated for renewed production, and one major new plant was opened in Windsor. Windsor Ceramic Tile Canada Ltd. was totally engineered and supplied by German specialists. Initial production is focussing on glazed mosaic tiles. Ultimate capacity is expected to be 2.3 million m^2, most of which will be exported to the U.S.A. Fireclay imported from Ohio is blended with minor amounts of local clay and nepheline syenite.

The former Thunderbrick plant near Thunder Bay is being renovated for split floor tile production exclusively, using a Saskatchewan stoneware clay. Initial production was planned for mid–1986.

Sanitaryware

Ceramic sanitaryware fixtures are made by three companies in Ontario, using china clay and ball clay imported from the U.S.A., and silica and nepheline

syenite from domestic sources. Production is by slip–casting and single–fire glazing.

American Standard Products Ltd. supplies markets across Canada from its Toronto plant. The Trenton plant of Crane Canada Inc. is one of three Crane plants in Canada. Waltec Bathware, a division of Emco Ltd., operates solely from its plant in Cornwall.

Electrical Porcelain

Three Ontario companies produce electrical porcelain products from imported kaolin clays, feldspar and talc, batching them with Ontario silica and nepheline syenite. Hamilton Porcelains Ltd. of Brantford makes a wide variety of custom refractory ceramic components, largely for the electrical industry, exporting 80 percent of its production to the U.S.A., Japan and Europe. Smith & Stone Ltd. manufactures thermoset, thermoplastic and porcelain ceramic insulators at its Georgetown plant. Electro Porcelain Company Ltd. makes a range of low voltage insulating products at its plant in Waterloo.

Refractories

Ten plants in Ontario produce a range of clay refractory products that include refractory mortars, castables and ramming and gunning mixtures, largely for the steel, glass and cement industries. Stiff competition prevails in a shrinking market caused by stagnant conditions in the consumer industries. All the refractory clays are imported from the U.S.A.

Flowerpots, Filter Tile

Halton Ceramics Ltd. of Burlington is Canada's only producer of clay flowerpots and filtration tiles. The company supplies about 20 percent of Canada's market for clay flowerpots, the rest being imported from the U.S.A., Germany and Italy. Plastic is gradually increasing its predominant share of the flowerpot market because of lower cost and easier handling. However, retail consumers prefer the appearance of clay pots, and are willing to pay a higher price for them.

A small specialized market for clay filtration tiles is served throughout North America, including Mexico.

Art Pottery

Art potters include both small commercial manufacturers and hobbyists making clay–bodied ceramic ware mainly for decorative purposes. Vases, ashtrays, figurines and giftware, and artistic kitchenware are among the most common products. Slip casting, wet pressing, jiggering, jolleying and hand throwing techniques are used in shaping the pieces, and electric furnaces are most often used for firing. Most of the clay raw materials are imported from the U.S.A. and distributed through pottery supply houses.

Other Products

Clays are used for many other industrial purposes such as fillers in paper, paint, rubber and plastics, absorbants such as cat litter, for drilling muds, and numerous minor applications. Currently no Ontario clay/shale raw materials are used in these applications.

Introduction

Clay is a natural, earthy fine–ground material composed largely of a group of crystalline minerals known as the clay minerals. These minerals are hydrous silicates composed mainly of silica, alumina and water. Several of these minerals also contain appreciable quantities of iron, alkalis and alkaline earth elements. The term "clay" may also be used for any fine grained, natural earthy, argillaceous material in which case, the term includes clay, shale, or argillite and some argillaceous soils.[1]

Clay is an abundant natural raw material with a variety of uses and properties which will be discussed in the ensuing chapters. In the first three chapters, the clay and shale resources of Ontario are described. These chapters are included to give the reader a basic knowledge of the resources of the province, previous and current applications for known deposits and potential, yet untried or unproven, applications for both well–characterized deposits and deposits that have not yet undergone significant investigation.

The remaining chapters discuss manufacturing industries which use clay raw materials. Some of these industries use domestic clay raw materials, some use imported clay raw materials and some substitute non–clay raw materials in their process. These chapters show the magnitude and scope of the industries that use clay raw materials and the importance of the clay and shale resources of Ontario to its economic well–being.

An important aspect in virtually all industries using clay raw materials is technological advancement. For the most part, in Ontario, new technology is having an impact on existing industry as opposed to creating new industry. This new technology includes increasing energy efficiency, automatic handling systems and electronic process control. If relevant, the application of technological advances, both domestic and foreign in origin, is described in the context of each chapter. The creation of new industry is discussed in the chapter on kaolin resources and in Part IV on other clay–using industries. The kaolin resources of the province currently are not being exploited, and may be the foundation of new industrial growth.

Sources used for this document include the open literature, information obtained from industry personnel, descriptive literature provided by manufacturers and suppliers, and information on file at the Ontario Research Foundation, some of which was obtained on a related trip to Europe. Wherever possible, these information sources have been cited and referenced in as much detail as possible.

1. Patterson, S.H. and Murry, H.H. "Clays, Industrial Minerals and Rocks." 4th Ed. Edited by S.J. Lefond. American Institute of Mining, Metallurgical and Petroleum Engineers Inc., Port City Press, p.519–586, 1975.

Industry Overview

Ontario clays and shales have been the principal raw materials for the making of brick, drainage tiles and sewer pipes since well before the keeping of statistics. They have also been used in the making of flue liners, floor tiles, structural and partition tiles, filtration tiles, art pottery, flower pots, expanded aggregate and rock wool.

Imported clays are used in the production of refractories and in the making of sanitaryware, electrical porcelain, whiteware, stoneware, earthenware, floor and wall tiles, and art pottery. They have also been used with domestic clays in the making of flue liners and sewer pipes. A historical record of the number of plants producing various clay products is given in Table 0.1.

The heavy clay products industry is that segment of the ceramics industry which deals mainly with construction materials such as bricks, tiles, sewer pipes and flue liners. In early times the industry was characterized by a profusion of small labour–intensive plants using local surface clays and firing with wood. Today only a few remain, and these have become highly automated and dependent on shale, using gas–fired continuous tunnel kilns. More bricks are produced annually in 8 plants today than were produced in 186 plants in 1906.

Paleozoic shales of the Georgian Bay, Queenston and Arkona Formations are the most important raw materials for Ontario's heavy clay products. They are illitic shales, generally red–burning with a short firing range, and their successful utilization in the production of quality products is a tribute to Ontario's heavy clay products industry.

With few exceptions, Ontario's surface clays are poorly suited for the manufacture of ceramic products. Almost all of them have an origin linked to the glacial history of the province. They are impure illitic clays, more or less calcareous and red or buff–burning. In fact many are so calcareous that they fail to vitrify, and burn instead to a soft porous nearly white body of inferior quality. Where some of the lime has been removed by leaching, a denser, harder, less porous red–fired body of improved quality may result. Ontario's brick industry, once founded on clay, was forced by quality considerations to use shale, with the result that many former rural brick plants without easy access to shale were converted to the production of clay drainage tiles. Today, in the face of competition from plastic drainage tubing, few clay tile plants remain.

The Cretaceous kaolin clays of the Moose River Basin in northeastern Ontario have the potential to reduce costly imports of high quality ceramic and filler clays plus many finished ceramic products. Remoteness, difficult access, heavy overburden and muskeg have hindered the exploration and development of these deposits. But except for small nearby occurrences of similar clays within the topographic expressions of the Cargill and Martison Lake carbonatites, the Moose River clays are unique in Ontario, and their economic development may ultimately be realized.

Clays and finely ground shales have several unusual properties that make them suited for ceramic purposes. These are the properties of plasticity and vitrification. Plasticity is recognized in dry clays and finely–ground shales when the addition of water in sufficient amount permits the moulding of the mass into any desired shape. Vitrification is a condition of partial fusion whereby a glassy bond is formed by heat. Vitrification of a clay or shale body results in greater density and hardness, and decreased porosity and absorption.

Some clays have other uses besides ceramics. Imported kaolin is used extensively as an industrial filler, particularly for filling and coating paper. Dolomitic shale of the Rochester Formation has a natural composition for rock wool and was used for that purpose at Thorold for 44 years. Georgian Bay Shale was used for making expanded aggregate (Haydite) in Mississauga for 37 years, and for making coated expanded aggregate for a subsequent 15 years.

TABLE 0.1 HISTORICAL RECORD OF THE NUMBER OF PLANTS PRODUCING VARIOUS CLAY PRODUCTS.

	1906	1929	1964	1979	1985
Bricks	186	97	25	15	8
Drain Tiles	51	84	31	18	5
Other Heavy Clay Products	19	23	4	3	2
Total Number of Plants Operating	192	145	54	28	15

Note: Some plants produce more than one product

Part I — Resources

Chapter 1 — Clay Resources of Ontario

INTRODUCTION

Clay is widespread in Ontario, but except for the Mesozoic kaolinite clays of the Moose River Basin in northeastern Ontario, all are of the low grade illite type, the product of Pleistocene glaciation. Actually, the surface clays of Ontario are a mixture of clay minerals and non–clay materials. Among the latter are included quartz, feldspar, calcite, dolomite, and minor amounts of other minerals and organic debris. Both clay and non–clay minerals were derived from bedrocks through physical and chemical weathering. And since the principal weathering agents were the glacial ice sheets of the last million years, the compositions of the surface clays closely reflect the underlying bedrock from which they were scoured.

Clays derived from shales or granitic rocks are typically low in lime content, and hence achieve a greater degree of vitrification on firing, and a red colour due to oxidation of iron. However, clays derived largely from carbonate rocks, which predominate in the lowlands of the Great Lakes and James and Hudson Bays, are limey, and on firing may fail to vitrify, but produce instead a less dense and more porous yellow or buff body of inferior strength and durability.

Glacial events of the last million years have had the most significant impact on the character and distribution of surface clays in Ontario. Soil and rock fragments gouged from the bedrock were deposited from the ice sheets in thick dense masses of till. Varved clays were rhythmically laid down in glacial lakes and ponds marginal to the melting edges of the glaciers. In warmer times, stratified clay, silt and sand derived by stream erosion of adjacent till plains, was deposited in lakes and ponds, and on the flood plains of rivers.

The glacial history of Ontario is summarized by Guillet,[2] and described by Hewitt and Karrow,[4] Zoltai[12] and Prest.[9] Previous studies on Ontario clay deposits have been performed by Keele,[6] Vos,[11] Guillet[3] and Kwong et al.[8]

Clay was the principal raw material in three plants producing drainage tiles in Ontario in 1985. It was no longer in use for brickmaking, or for sewer pipe, flue liners or flowerpots; and it has not been used for expanded aggregate. In 1964 it was the principal raw material in 33 drainage tile and brick plants in Ontario.[2]

CLAY DEPOSIT TYPES

Most of Ontario is covered by a mantle of glacial till that remained after the melting of the most recent glacial ice 5,000 to 14,000 years ago. A variety of stoneless clays was deposited about the same time and subsequently formed horizontal layers in lakes, ponds and river valleys. Reworking and redistribution of these deposits has resulted in further deposits, sometimes with improved ceramic properties. The various types of clay deposits are briefly described in the following notes.

Stoneless deposits are of prime interest for clay products. Most often they are deposited from quiet waters, having been carried there in suspension in river waters draining adjacent till plains. Deposits are often stratified in horizontal layers of clay, silt and fine sand, and they can be recognized as varved clays, non–varved lake clays, interglacial clays, marine clays and flood plain clays. Certain unstratified clays developed to shallow depths on till plains may be of local interest.

Varved Clays

Varved clays are the most typical deposits in glacial lakes and the most widespread stoneless clays in Ontario. They consist of alternating layers of clay and silt representing deposition during winter and summer, respectively. Clay layers are uniform, smooth, dense and darker coloured; silt layers are more variable, lighter coloured and thicker. Clay layers reflect quiet water conditions beneath winter ice; silt layers reflect the increased flows from spring runoff and occasional turbulence of storm and flood. Clay layers are typically less than 2 cm thick; silt layers may be more than twice as thick as their clay counterparts. A varve is a clay–silt couplet representing one year's deposition.

Varved clays were typically deposited in lakes and ponds that formed along the melting edges of the glacial ice. Today they are exposed in river and lake banks or on the flanks of bedrock and morainic hills. Paisley Brick and Tile was using varved clay in making drainage tiles in 1985; 11 brick and tile plants used it in 1964.[2]

Non–Varved Lake Clays

Irregularly stratified deposits of stoneless clay have accumulated on lake beds in more moderate conditions than those necessary for varve formation. They may be rhythmically layered in coarse and fine

material, reflecting seasonal changes, but the layers are less uniform in composition and thickness than in varved clays. Wood fragments, leaves, snails and clam shells, indicative of non–glacial conditions, are occasionally present, as are thin lenses of sand or fine gravel due to beach or deltaic conditions. Only Norwich Brick and Tile (1979) Limited uses non–varved lake clay in making drainage tiles, whereas 17 plants were active in 1964.[2]

Interglacial Clays

Interglacial clays are stratified lake clays that were deposited under moderate climatic conditions between periods of glaciation. In Ontario they have only been recognized in the Toronto area and on the James Bay Lowland. They are distinguished from younger clays only by isotopic dating and faunal studies, or by their position beneath obvious glacial deposits.

Interglacial clays were once the principal raw material for six brick plants on Greenwood Avenue in east Toronto.[6] They were also exposed and utilized in the clay pit adjoining the Don Valley plant of Toronto Brick Company,[2] but they have not been used for many years.

Marine Clays

Marine clays are stratified deposits of clay, silt and sand distinguished in Ontario by the presence of marine shells and a moderate content of montmorillonite. They are recognized in the Ottawa–St. Lawrence river valleys and the James Bay Lowland.

Marine waters invaded the Ottawa and St. Lawrence valleys in the wake of the receding ice sheet, depositing nearly 60 m of stratified clay and sand. Dochart Brick and Tile Company at Arnprior was the only plant using marine clay, making drainage tiles and flowerpots until the plant closed in 1982.

Flood Plain Clays

These are shallow deposits of stratified silt and clay deposited on low flat banks of rivers and streams in times of flood. Flood plain clays are young deposits typically comprising reworked and redeposited clays, or the finer portions of tills, interlayered with fresh water shells, wood fragments and other plant debris. Although some are small and localized, these clays may have improved ceramic properties because of the removal of some of their lime by leaching. In 1964 there were four plants using flood plain clays,[2] but in 1985 there were none.

Stoneless Till

Tills are unsorted mixtures of clay, sand and silt with a variable content of rock fragments. Till plains that have subsequently been covered by lake waters, as in Essex, Kent and Lambton counties, have been modified in places by wave and current action to an almost stone–free condition in their upper parts. The thin modified portion usually has improved ceramic properties because of the leaching of some of its lime content. In 1964, 10 plants used these clays for all or part of their needs.[2] In 1985, only Dresden Tile Limited was active, but it did not plan to operate in 1986.

DISTRIBUTION AND CHARACTER OF ONTARIO CLAYS

Because of their deposition in the glacial Great Lakes, which were larger ancestors of the present Great Lakes, clay deposits tend to be marginal to the present shorelines of the Great Lakes. Additionally, in northern Ontario, extensive deposits of varved clay were deposited from glacial Lake Agassiz in the west and Lakes Barlow–Ojibway in the east. Figure 1.1 summarizes the general ceramic character and distribution of Ontario clays which are detailed more fully in the following notes.

TORONTO

Interglacial Clays

The Pleistocene clays that first found use in brickmaking were the interglacial clays unique to the Toronto region. Known as the Don and Scarborough beds, these clays were deposited about 100,000 years ago in a warm climate between the Illinoian and Wisconsinan glacial stages. Exposed only in deeply cut river valleys, subway excavations and the Scarborough Bluffs, these clays appear to be restricted to an area within 8 km of Lake Ontario between Highland Creek on the east and Humber River on the west.

The Don Beds are a lower fossil–bearing sequence of stratified sand, clay and fine gravel that was deposited in a lake 18 m higher than Lake Ontario at a time when the climate was about 3°C warmer than at present.[10] The upper Scarborough Beds are a similar stratified sequence which was deposited in a lake 60 m higher than Lake Ontario in a climate that averaged 6°C cooler than the present.

Clay from the Scarborough Beds was particularly prized by early brickmakers for its rich maroon fired colour. Soft mud bricks were produced by six plants on Greenwood Avenue in east Toronto.[6] The John Price plant, owned by Toronto Brick Limited,

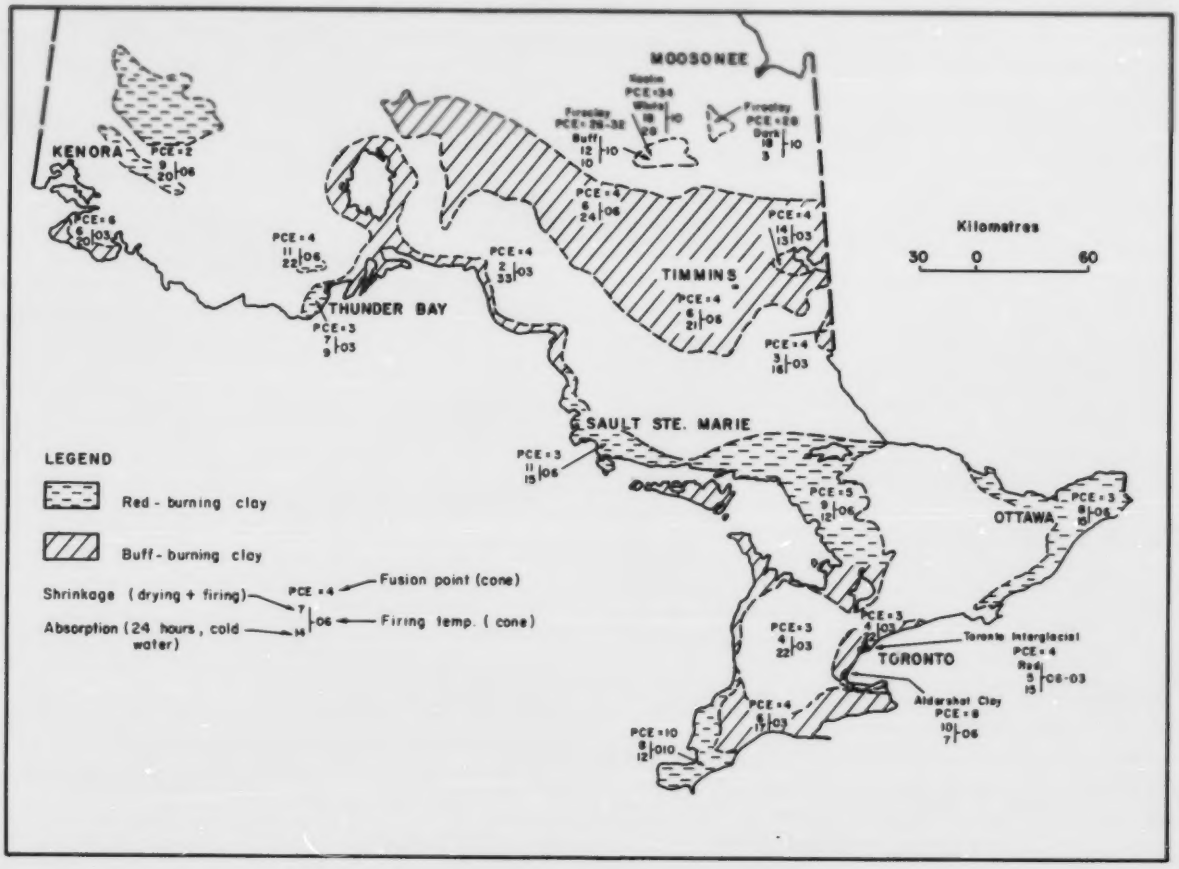

Figure 1.1 Ceramic properties of Ontario clays.

was the last to close in 1962. It and a similar clay section in Toronto Brick's Don Valley pit are described in an earlier report.[2]

Clay from the Scarborough Beds had good plasticity and could be vitrified between cones 06 and 03 with a total linear shrinkage (i.e. drying plus fired shrinkage) of 5 percent and a cold water absorption of 15 percent. Its maroon fired colour was probably due to its derivation from Georgian Bay Shale which is the bedrock in the Toronto area.

Other Clays

Above the interglacial clays in Toronto are varved clays and scattered deposits of stratified clay, all very limey in composition. The varved clays were deposited from meltwater ponded between glacial ice in the Lake Ontario basin and high ground north of the present shoreline. Several thin stony layers within the Don Valley pit reflect a fluctuating ice front which periodically overran the area of varved clay deposition. The varved clays have good plasticity and burn to a yellow–buff colour, with a total linear shrinkage of 4 percent and absorption of 22 percent at cone 03.

HAMILTON–BURLINGTON AREA

The best clay in southern Ontario was deposited in two shallow lagoons separated from glacial Lake Iroquois, the forerunner of Lake Ontario, by gravel bars at the mouth of the Dundas valley. Sources of the clay were nearby eroding terraces of Queenston Shale. Both deposits were less than 1.5 m thick and of limited extent, one extending into west Hamilton, the other east past Aldershot.

The clay is highly plastic, smooth, red in colour and red–burning. It is nearly of stoneware quality, being steel hard at cone 06 with a total linear shrinkage of 10 percent and an absorption of 7 percent. It has a fairly long vitrification range and fuses (PCE) at cone 8.

Both clay deposits were extensively worked for sewer pipe, flowerpots, pottery and other clay prod-

ucts, but urban development in Hamilton and Highway 403 through Burlington have rendered the remaining reserves unavailable. In 1962 National Sewer Pipe Limited scraped together the last of the clay on its lands in the present vicinity of Highway 403 and King Road. It still operates quarries in Queenston Shale on King Road 1 km north of Highway 403.

The possibility that other similar deposits may have formed in shallow depressions along the base of the Niagara Escarpment adjacent to eroding exposures of Queenston Shale should not be discounted.

LAKE ERIE SHORE

Small deposits of stoneless clay are irregularly distributed along the Lake Erie shore from Welland to Chatham, and north to Brantford and London. Some are grey varved clays, while others are brown massive or thickly stratified deposits. All are rather sandy and limey, burning to a yellow–buff colour at cone 03 with a total linear shrinkage of 6 percent and an absorption of 17 percent.

ESSEX, KENT AND LAMBTON COUNTIES

An extensive till plain in the southwest corner of the province was inundated by glacial meltwaters during early stages in the retreat of the glacial ice. Waves and currents appear to have caused a sifting, sorting and leaching action which has resulted in an almost stonefree till in the upper 1 m and much improved ceramic properties. The clay is plastic, has a moderate firing range, and burns to a dense red body at a low temperature. At cone 010 it has a total linear shrinkage of 8 percent and an absorption of 12 percent. It has a PCE of cone 10.

Despite its shallowness, this clay attracted more brick and tile plants than anywhere else in Canada. Baker[1] described 68 plants in 1906. There were 11 in 1962,[2] but only one in 1985, and it had announced its closure in September of that year. Originally, many of these yards were brick producers, but latterly only drainage tiles were produced in the area.

Scattered pockets of stratified flood plain clays washed from adjoining till areas are also present. These have properties similar to the stone–free till, and were similarly utilized.

HURON HIGHLANDS

The large interior highland region of southwestern Ontario, between Galt and London on the south and Walkerton and Dundalk on the north, was largely free of ice during the final stages of the last glaciation. Extensive till moraines were left by the flanking ice lobes, and a few shallow deposits of stoneless clay were formed by the re–working of these materials. These clays are predominantly limey and buff–burning because they were derived from limestone and dolostone bedrock. At cone 03 they have a total linear shrinkage of 4 percent and absorption of 22 percent.

However, due to more complex depositional histories, involving perhaps several stages of re–working and leaching, a few deposits with improved ceramic properties are known. At Listowel, for example, finely laminated silty clay 2 m thick burns red with a moderate firing range. At cone 06 it has a combined drying and firing shrinkage of 6 percent and absorption of 15 percent. In 1962 it was being used for drainage tile,[2] but the plant has since closed.

LAKE HURON AND SOUTH GEORGIAN BAY

Varved or stratified clays in deeply–cut river banks marginal to Lake Huron, southern Georgian Bay, and on Manitoulin Island, were deposited from glacial Lakes Algonquin and Warren. They are highly plastic, calcareous, and burn to a yellow–buff colour. At cone 06 they have a total linear shrinkage of 8 percent and absorption of 18 percent. Drainage tiles are still made from a mixed section of varved and stratified clays on the north bank of the Saugeen River east of Paisley.

OTTAWA–ST. LAWRENCE VALLEYS

Stratified pink and grey marine clays and sand deposited from the Champlain Sea in the valleys of the Ottawa and St. Lawrence Rivers are the most widespread clays in eastern Ontario. The clay is particularly common between Hawkesbury and Ottawa, underlying broad flat plains marginal to the Ottawa River. A thin capping of sand reflects beach conditions that marked the final retreat of marine waters. North of Ottawa to Pembroke an increase in the proportions of sand and silt indicate shallow water conditions. Marine waters of the Champlain Sea entered Ontario from the Hudson River valley when the land surface had been depressed by the weight of glacial ice. The sea retreated as the land gradually rebounded, free of its glacial burden.

Champlain clay is highly plastic and red–burning. At cone 06 it has a total linear shrinkage of about 8 percent and an absorption of 15 percent, but the firing range is short. The clay fuses at cone 03. Champlain clay was used at Arnprior until recent years, mostly for making drainage tiles but latterly also for flowerpots.

NORTH GEORGIAN BAY

Varved clays are irregularly distributed between Precambrian ridges of predominantly granitic gneisses along the Georgian Bay shore north from Gravenhurst and along the north shore of Lake Huron. These clays were deposited from glacial Lake Algonquin or from later lake stages that filled the Huron basin during the interval 6,000 to 12,000 years ago. They are red–burning clays of good plasticity, and at cone 06 they have a total linear shrinkage of about 9 percent and absorption of 12 percent.

NORTHEASTERN ONTARIO

The Clay Belt of northeastern Ontario is the bed of the former glacial Lake Barlow–Ojibway which occupied the area north of the height of land and was ponded against the edge of the receding glacier. Thick sections of varved clay are typical and widespread in the Timmins–Cochrane–Hearst–New Liskeard area. They are moderately plastic, buff–burning, and have a short firing range. At cone 06 they have a total linear shrinkage of 6 percent and absorption of about 23 percent. Source of this very limey composition was apparently the Paleozoic carbonate rocks of the James Bay and Hudson Bay lowlands to the north.

Near Lake Abitibi, close to the Quebec boundary, a yellow–burning clay of unusually fine properties occurs. Deposits of massive brown clay and grey varved clay a few kilometres east of Iroquois Falls are both highly plastic, smooth and buff yellow–burning. The brown clays are steel hard at cone 010, and are not overfired at cone 03 where total shrinkage is 14 percent and absorption 13 percent.

Kaolinitic clays of the Moose River Basin north of Kapuskasing and Hearst are described in a separate chapter.

NORTHWESTERN ONTARIO

Varved clays are widespread in northwestern Ontario as a result of a succession of post–glacial lakes in the Lake Superior basin and glacial Lake Agassiz. Thick deposits are found in the banks of deep river valleys along the north shore of Lake Superior. They are silty, limey and buff burning. At Marathon and Nipigon they burn to a soft porous body at cone 03; total linear shrinkage is only 2 percent and absorption nearly 30 percent. Near Dorion the clays fire to a denser buff body with a total linear shrinkage of 9 percent and absorption of 14 percent.

Brown stratified clays are common at Thunder Bay, and have been used intermittently for bricks, drainage and floor tiles at Rosslyn.

Massive red clay is found over a small area near Finmark, 40 km northwest of Thunder Bay. It is highly plastic and burns with a short firing range to a pale red body at cone 06, with a total linear shrinkage of 11 percent and absorption of 22 percent.

Glacial Lake Agassiz occupied much of the Kenora area and extended west into Manitoba. Scattered deposits of stratified clays mark its former presence. At Dryden the clays are highly plastic and red–burning. At cone 06 they have a total linear shrinkage of 9 percent and absorption of 20 percent. In the Rainy River and Fort Frances area they are limey and buff burning. At cone 03 they exhibit combined drying and firing shrinkage of 6 percent and absorption of 20 percent.

Clays throughout northwestern Ontario are also described by Keele[6] and most recently by Kristjansson et al.[7] Clays of Thunder Bay are further described by Keele.[5]

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Chapter 2 — Shale Resources of Ontario

INTRODUCTION

Paleozoic shales are the major raw materials for the manufacture of heavy clay products in Ontario. Surface clays are now used only for drainage tile and as a minor additive in some art pottery and floor and wall tiles.

Eighteen Ontario shales, all but one being Paleozoic, have been described in a previous report.[2] Of these, only three were being used in 1985 in the production of heavy clay products. Georgian Bay Shale was being used in two brick plants and one cement plant in the Toronto area. Queenston Shale was being used in five brick plants between Hamilton and Brampton, and in one at Ottawa; it was also being used for flowerpots and filtration tile at Burlington, drainage tile at Wallenstein, and flue liners at St. Thomas. Arkona Shale was being used for drainage tile at Parkhill and flue liners at St. Thomas. These three shales were also the principal raw materials in use in 1962 when a previous study of the heavy clay products industry was undertaken.[1]

Georgian Bay Shale was used for making Haydite expanded aggregate at Mississauga from 1928 to 1980. Also, the Collingwood Member of the Lindsay Formation has shown promise for coated aggregate, hindered mainly by restricted access.

Mineral wool was made from dolomitic Rochester Shale at Thorold from 1938 to 1978. Both Georgian Bay and Queenston shales mixed with 30 to 40 percent dolomitic lime could also be used. Indeed, most Ontario shales mixed with suitable additives will make mineral wool of varying qualities.

Shale of the Collingwood Member of the Lindsay Formation in south–central Ontario is a potential source of hydrocarbon oil, as are black shales of the Kettle Point Formation of southwestern Ontario and the Long Rapids Formation of northeastern Ontario.

In northwestern Ontario, Precambrian Rove Shale has been used in the making of bricks, drainage tiles and split floor tiles.

Shale resources are extensive in Ontario, although unevenly distributed geographically. Scarcity is not a threat to their continued utilization except in the Toronto–Hamilton area through pressures of urbanization and competing land uses. Except for these pressures, it is a fortunate coincidence that the principal brick shales, the Georgian Bay and Queenston Formations, are almost restricted in their occurrence to the major market area.

GEOLOGY

Ontario is dominated by a central upland area of crystalline Precambrian rocks, flanked on the north and south by Phanerozoic lowlands. The principal geological regions of Ontario are illustrated in Figures 2.1 and 2.2. Except for the brittle Proterozoic shales of the Rove Formation in the Thunder Bay area, all Ontario shales are Paleozoic and largely confined to the lowlands.

The Phanerozoic lowlands consist of relatively undisturbed and unaltered Paleozoic sedimentary rocks, irregularly mantled by unconsolidated deposits of Pleistocene and Recent age. The southern lowland is divided by the Frontenac Axis into the Great Lakes Lowland and the Ottawa–St. Lawrence Lowland. Shale formations in the Great Lakes Lowland are the most important sources for clay products in Ontario. Here, a sequence of Cambrian to Devonian sedimentary rocks dips gently to the southwest towards the Michigan Basin (Figure 2.2). In the extreme southwest portion of the province these rocks are about 1,500 m thick.

A thinner portion of the Paleozoic record is represented by Cambrian and Ordovician sedimentary rocks in the Ottawa–St. Lawrence Lowland east of the Frontenac Axis. These rocks dip gently to the southeast, but unlike the little–disturbed Great Lakes section, these rocks have been disturbed by block–faulting. A restricted occurrence of shales comparable to the Queenston and Georgian Bay formations is present in the Ottawa area and is utilized there for brickmaking.

The Hudson Bay Lowland is underlain by nearly flat Paleozoic sedimentary rocks with many similarities to those in the south. However, a restricted occurrence of Mesozoic sediments in the Moose River Basin is a potential source of kaolin clays not found elsewhere in Ontario. These are separately described in the next chapter.

An outlier of Ordovician and Silurian rocks has been preserved by block–faulting in the Timiskaming area of east–central Ontario. However, shale is not present in significant amounts.

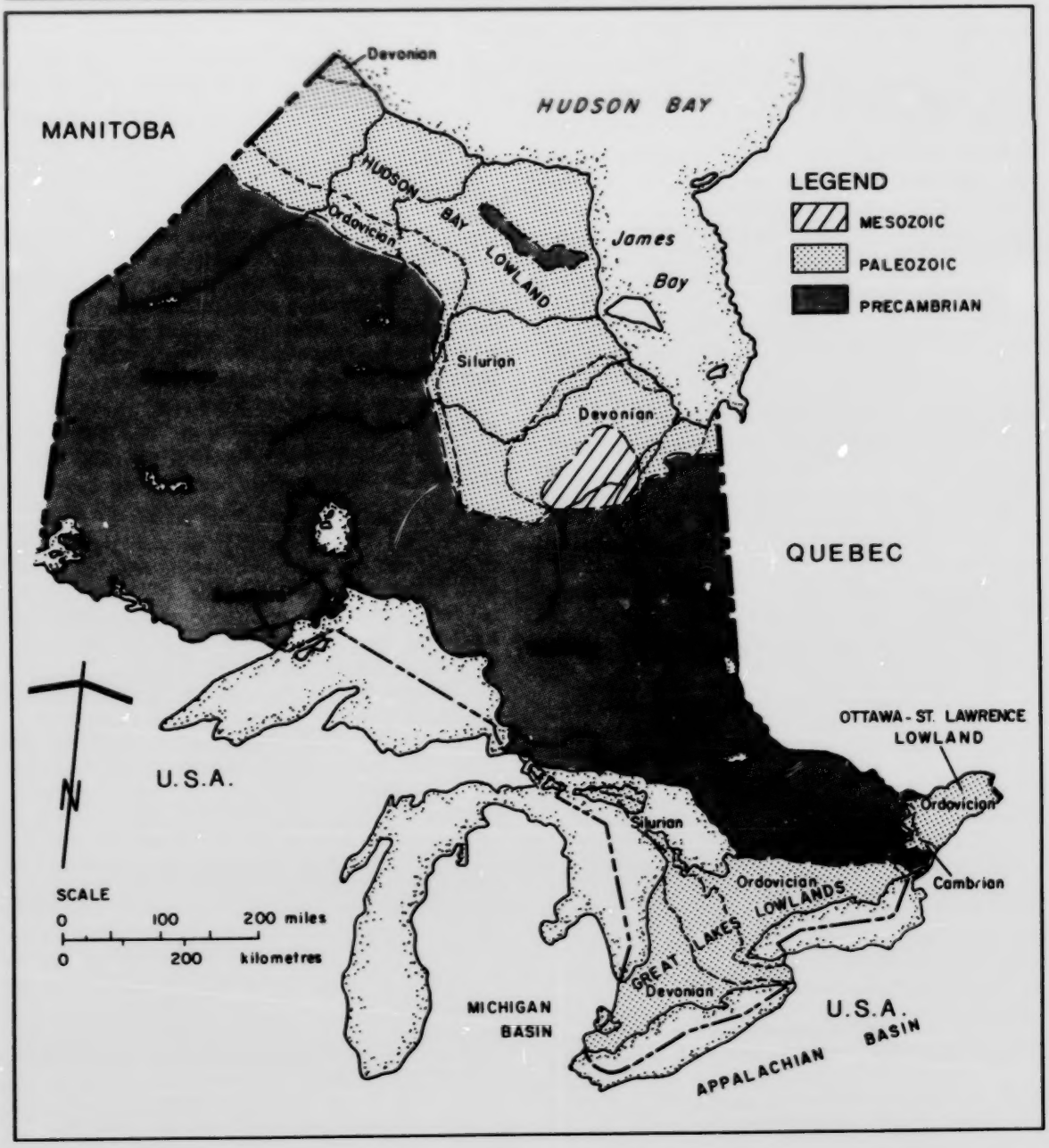

Figure 2.1 Generalized geology of Ontario.

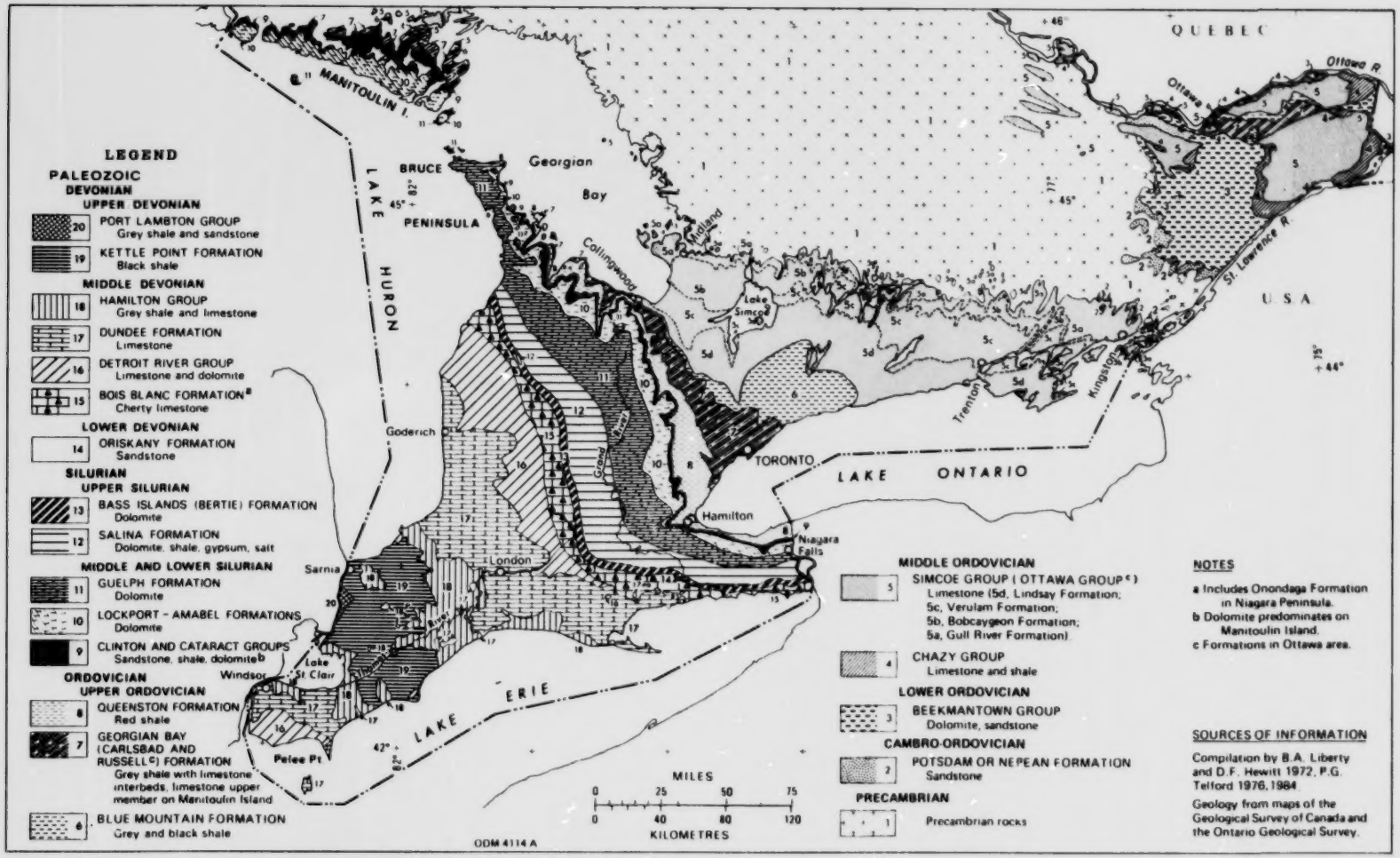

Figure 2.2 Geology of southern Ontario.

SHALES OF COMMERCIAL INTEREST

Four shale formations — the Rove, Georgian Bay, Queenston and Arkona — are briefly described in the following notes. These are the principal sources of raw material for heavy clay products in Ontario. However, the reader should note that there are other shales which may have special value for particular purposes. For example, shale of the Blue Mountain Formation appears to be an attractive raw material for bricks and other heavy clay products. The Collingwood Member of the Lindsay Formation may have special value for expanded aggregate. Also, portions of the Rochester Formation have been used for making rock wool because of a nearly ideal composition. These and other shales are described more fully in a previous volume.[2]

SHALES OF PRINCIPAL INTEREST

Rove Formation

The Proterozoic Rove Formation in the Thunder Bay area is the oldest rock in Ontario that still retains much of its shale characteristics. However, it is inclined to be brittle and in some places grades to slate. Even when finely ground, it develops insufficient plasticity for extrusion equipment unless mixed with a suitably plastic clay. In this way it was used by Thunderbrick Ltd. (1976 – 1982) in the making of bricks and split floor tiles. Earlier it was used for dry pressed bricks.[2]

Rove Shale is the upper of three formations that comprise the Animikie Group. It overlies the Gunflint Formation, mostly taconite, and the basal Kakabeka Conglomerate. Shales of the Rove Formation are grey–black, medium to very thin bedded, brittle fissile rocks interlayered in places with siltstone and greywacke. Spheroidal calcite concretions up to 2 m in diameter and 1 m thick are occasionally present. The formation is essentially flat–lying and widely distributed southwest of Thunder Bay and along the west side of Sibley Peninsula. Narrow dikes and sills of brown–weathering diabase cut the Animikie rocks.

A more detailed description of the Rove Shale is given by Guillet.[2] Typical chemical and mineral composition is reproduced in Table 2.1, and ceramic properties in Table 2.2, based on samples from a roadside quarry on Sibley Peninsula used most recently by Thunderbrick Ltd.

TABLE 2.1 ROVE SHALE, ANALYTICAL DATA.(2)

Chemical Composition (%)*	
SiO_2	60.7
Al_2O_3	15.7
Fe_2O_3	5.84
CaO	0.68
MgO	2.72
Na_2O	1.52
K_2O	3.70
TiO_2	0.74
CO_2	1.42
H_2O+	3.38
H_2O-	0.82
SO_3	1.51
MnO	0.03
Total	98.8
Soluble Salts	0.85
Ignition Loss	7.29
Mineral Composition (%)*	
Quartz	30
Calcite	0
Dolomite	1
Na/Ca Feldspar	3
Potash Feldspar	1
Clay Minerals	65
Illite	Abundant
Chlorite	Common
Expanding minerals	Minor

*6 m section exposed in roadside quarry, Sibley Peninsula

Georgian Bay Formation

Formerly known by the names Meaford and Dundas, the Georgian Bay Shale comprises two similar conformable units overlying shales of the Blue Mountain Formation. The two units were previously distinguished only with difficulty, the distinction being based on fossil content and frequency of hard limey and sandy layers. Except for these layers, the shale is markedly soft and bluish to greenish grey in colour. Formerly used more extensively in brickmaking (Photo 2.1), and in the production of expanded aggregate, Georgian Bay Shale was being used in two brick plants and one portland cement plant in the Toronto area in 1985.

Georgian Bay Shale is thin to medium bedded, consisting largely of moderately soft shale, but interlayered also with hard beds and lenses of limey or sandy composition. These hard layers increase in frequency towards the top of the section as well as to the north. The formation underlies the Toronto area as far west as Streetsville, and persists beneath the drift along the base of the Niagara Escarpment to outcroppings on Georgian Bay and Manitoulin Island. Whereas hard layers typically comprise 10 to 20 percent of the lower Georgian Bay unit in the Toronto area, and perhaps 30 percent of the upper unit, they are noticeably more common in outcrops

TABLE 2.2 ROVE SHALE, CERAMIC PROPERTIES.(2)

	Upper 2.8 m*			Lower 3.2 m*		
Water of plasticity, %	16			16		
Drying Shrinkage, %	1.6			–		
PCE	7			7		
Firing temp. °C	900	1000	1080	900	1000	1080
Cone	010	06	03	010	06	03
Fired Shrinkage, %	+0.5	0.3	3.2			
Water absorption						
24 hr. cold, %	17.8	16.8	8.6	14.7	12.8	4.0
5 hr. boiling, %	22.7	22.2	13.5	17.7	15.6	7.0
Specific gravity	1.66	1.68	1.87	1.82	1.89	2.13
Colour	salmon → pale red			salmon → red		
Hardness	soft → hard			almost hard → very hard		
Remarks	Low plasticity; gritty textured; weakly consolidated					

*6 m section exposed in roadside quarry, Sibley Peninsula

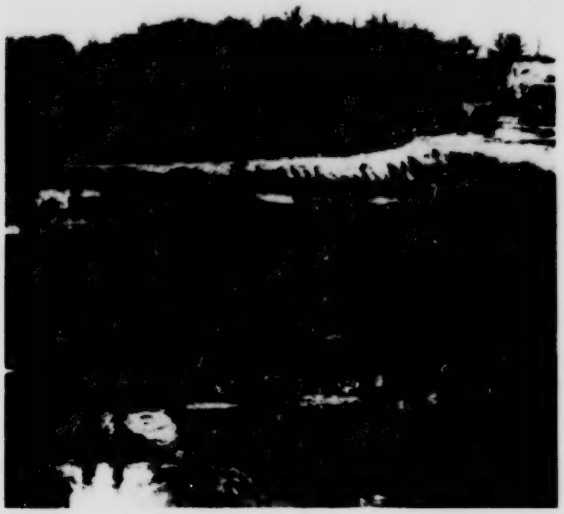

Photo 2.1 Don Valley quarry of Toronto Brick Company, ca 1950s. Georgian Bay Shale beneath interglacial and glacial clays. Photo courtesy Clay Brick Association of Canada.

at Georgian Bay, and on Manitoulin Island the upper unit is represented by argillaceous limestone. Georgian Bay Shale also occurs southeast of Ottawa where the upper and lower units are referred to as the Russell and Carlsbad Formations, respectively.

Individual shale beds of the Georgian Bay Formation do not vary appreciably in composition from place to place, but lime content of the overall formation increases proportionately with increasing frequency of hard layers. Improved ceramic performance is achieved by reducing or eliminating hard layers, and commercial practice sometimes uses manual or mechanical sorting to accomplish this. Table 2.3 shows the variations in chemical and mineral composition of the various elements that comprise the total formation.

Georgian Bay Shale has just sufficient plasticity for modern extrusion machines; eliminating hard layers improves its plasticity. The shale has a moderate firing range, and burns to an attractive salmon–red body. Minor amounts of gypsum and pyrite require neutralizing to prevent scum and efflorescence. Typical ceramic properties are outlined in Table 2.4.

Commercial use of Georgian Bay Shale in the making of expanded aggregate in the form of a crushed sintered product was demonstrated in the production of Haydite at Mississauga from 1928 to 1968, and in the production of coated aggregate from 1968 to 1980.

In 1961, four quarries were operating in Georgian Bay Shale as the principal raw material source for five brick plants and one expanded aggregate plant in the Toronto area. Detailed studies of the shale sections are contained in an earlier report.[1] Other shale exposures, including the St. Lawrence Cement quarry in Mississauga, the Humber River bank in Brampton, the Meaford Creek section at Meaford, and a section near Gore Bay on Manitoulin Island, have also been described earlier.[2] New analytical data from shale sections at Creemore and Meaford are included in Tables 2.3 and 2.4.

The Creemore sample was from a roadcut in Nottawasaga Township; it was tested by Kwong et al.[5]

Two Meaford samples, representative of the upper grey–green shale and the lower grey–blue shale, respectively, are from the quarry of the former Meaford Tile Company.

TABLE 2.3 GEORGIAN BAY SHALE, ANALYTICAL DATA.(5,4,6)

Chemical Composition (percent)

	1 Pure Shale	2 Limey Beds	3 Sandy Beds	4 Typical Average	5 Creemore	6 Meaford Blue	6 Meaford Green
SiO_2	58.74	34.7	63.6	55.7	56.75	59.83	58.93
Al_2O_3	17.90	8.0	15.0	15.3	15.84	12.88	12.16
Fe_2O_3	7.50			6.60	6.84	7.50	7.73
CaO	2.37	30.3	7.3	4.63	3.03	2.51	1.38
MgO	2.84	trace	trace	2.82	2.94	3.00	2.63
Na_2O	4.03			0.93	0.54	0.74	0.74
K_2O				3.51	4.79	4.06	4.06
TiO_2				0.89	0.80	0.91	0.95
Ignition Loss	8.26	24.7	9.3	9.22	8.23	8.20	8.45
Total	100.64	98.7	95.2	99.6	99.76	99.63	97.08

Mineral Composition (percent)

	4 Typical Average	5 Creemore
Quartz	28	25
Calcite	7	0.5
Dolomite	1	0
Na/Ca Feldspar	3	1.5
Potash Feldspar	0.5	2.0
Clay Minerals	60	70
Illite	Abundant	Abundant
Chlorite	Common	Abundant
Expanding Mineral	Not detected	Not detected

TABLE 2.4 GEORGIAN BAY SHALE, CERAMIC PROPERTIES.(1,5)

	4 Typical Average			5 Creemore			
Water of plasticity, %	18			22.6			
Green Strength, MPa				1.25			
Drying shrinkage, %	2.3			4.1			
PCE	5						
Firing temp., °C	900	1000	1080	915	1000	1050	1080
Cone	010	06	03	09	06	04	03
Fired shrinkage, %	0.1	0.6	2.4	0.5	4.1	7.9	8.2
Water absorption							
24 hr. cold, %	13.1	11.7	4.3	15.4	6.5	1.0	0.3
5 hr. boiling, %	14.6	13.8	6.8	16.0	6.8	1.1	0.3
Specific gravity	1.94	1.97	2.20				
Colour	salmon → brown			salmon → red brown			
Hardness	hard → very hard			hard → very hard			
Mod. of Rupture, MPa				9.0	21.5	30.9	39.1
Remarks	blistered and overfired at cone 03			slight efflorescence at cone 09			

Queenston Formation

One of the most distinctive rock formations in southern Ontario, the Queenston is a thick sequence of red shale prominently exposed along the base and lower terraces of the Niagara Escarpment. It occupies a position at the top of the Ordovician system in Ontario, overlying grey Georgian Bay Shale and underlying Whirlpool Sandstone of Silurian age. It is the principal raw material in five brick plants between Hamilton and Brampton, and one in Ottawa. It is also used in the making of flowerpots

TABLE 2.5 QUEENSTON SHALE, ANALYTICAL DATA.(1,5,3)

Chemical Composition (percent)

	1	2	3	4	5	6	7
	Fm.Av.	Weathered	Collingwood	Creemore	Huttonville	Georgetown	
SiO_2	51.28	56.28	39.82	51.32	58.96	50.1	55.4
Al_2O_3	13.9	16.0	12.76	13.6	12.24	15.0	16.0
Fe_2O_3	6.15	6.77	6.14	6.94	5.43	6.96	7.50
CaO	9.00	4.74	14.87	7.53	7.10	7.85	4.36
MgO	3.48	2.55	3.72	3.09	2.12	4.21	3.50
Na_2O	0.58	0.70	0.26	0.55	0.86	0.20	0.21
K_2O	3.60	3.93	4.19	4.39	3.50	4.65	4.86
TiO_2	0.72	0.85	0.51	0.64	0.66		
Ignition loss	10.62	7.94	17.49	11.68	8.88		
SO_3	0.26	0.33	0.03	0.03	0.03		
Total	99.8	100.1	99.99	100.0	100.01		

Mineral Composition (percent)

	1		3	4	5	8
	Fm.Av.	Range	Collingwood	Creemore	Huttonville	Georgetown
Quartz	26	18–34	20	25	30	25
Calcite	11	2–30	9	3	6	5.5
Dolomite	1.8	0–8	1.5	1	1	0
Na/Ca feldspar	1.3	0–7	1	1	1	1
Potash feldspar	trace	0–2	1	1	1	1
Clay minerals	60		67.5	69	61	67.5
Illite	abundant		abundant	abundant	abundant	abundant
Chlorite	common		common	common	common	common
Expanding mineral	trace		mid	trace	trace	mid

Samples:
(1) Average of nine quarries
(2) Typical weathered shale
(3) Bulk sample
(4) Channel sample
(4) Channel sample
(5) A. C. Martin quarry, lower 2 m
(7) A. C. Martin quarry, top 2.3 m
(8) Bulk sample from roadcut

TABLE 2.6 QUEENSTON SHALE, TYPICAL CERAMIC PROPERTIES.(1)

		1 Formation Average			2 Weathered Shale	
Water of plasticity, %		17			20	
Drying shrinkage, %		3.2			3.8	
PCE		4			5	
Firing temp., °C	900	1000	1080	900	1000	1080
Cone	010	06	03	010	06	01
Fired Shrinkage, %	0	0	0.9	0.5	2.1	3.5
Water absorption						
24 hr. cold, %	13.4	12.3	8.5	12.1	9.0	4.0
5 hr. boiling, %	14.2	15.2	11.5	13.5	11.0	5.5
Hardness		almost hard → hard			hard → very hard	
Colour		salmon → brown			salmon → red	

TABLE 2.7 QUEENSTON SHALE, CERAMIC PROPERTIES OF SELECTED SAMPLES.(5)

	3 Collingwood				4 Creemore				5 Huttonville				8 Georgetown			
Water of plasticity, %	20				16				15				16			
Green Strength, MPa	0.98				0.86				1.07				0.93			
Drying shrinkage, %	2.9				2.4				2.1				1.3			
Firing temp.,°C	900	1000	1080	1100	900	1000	1080	1100	915	1000	1050	1080	915	1000	1080	1100
Cone	09	06	03		09	06	03		09	06	04	03	09	06	03	
Fired shrinkage, %	0.4	1.1	1.6	1.5	1.0	1.1	1.9	1.4	0.1	0.5	0.5	1.2	1.2	2.0	2.7	2.7
Water absorption																
24 hr. cold, %	16.2	15.9	14.3	13.6	14.2	12.5	9.9	9.3	14.3	12.5	11.1	11.0	14.2	13.7	9.7	9.1
5 hr. boiling, %	17.3	17.1	16.1	15.3	14.9	14.0	12.1	10.7	15.0	14.4	13.3	13.2	14.9	15.1	12.3	10.9
Modulus of rupture, MPa	13.2	15.4	19.6	15.1	10.4	9.2	11.7	13.8	9.1	12.4	14.1	16.4	13.2	13.5	16.8	17.8
Hardness (Mohs)	6	6	7	7	6	6	7	7	6	6	7	7	6	6	7	7
Colour	buff → salmon				salmon → brown				salmon → red				salmon → red			
Remarks	slight efflorescence				efflorescence at cone 09				efflorescence at cone 09				efflorescence at cone 09			

Samples:
(3) Bulk sample from shallow excavation
(4) Channel sample from roadcut
(5) Channel sample from stream bank
(8) Bulk sample from roadcut

and filtration tiles at Burlington, flue liners at St. Thomas and drainage tiles at Wallenstein.

The Queenston Formation forms the shoreline of Lake Ontario from Niagara to Oakville, and its outcrop parallels the Niagara Escarpment northward through Owen Sound and Cape Croker, contributing a characteristic redness to the soils along its outcrop belt. It also occurs over a small area south of Ottawa. While much of the formation has a rather massive and uniform appearance, it is in fact thin to thickly bedded and somewhat variable in composition and ceramic suitability. Thin lenses of green shale, both horizontal and vertical, are erratically distributed but generally are more common near the middle of the shale sequence, contributing a proportionate increase in lime content. Nodular concentrations of gypsum, other soluble salts, and locally increased hardness and brittleness may further limit some exposures for clay products. In general, the shale breaks down readily by weathering, leaving a softer residual material somewhat leached of lime and with improved ceramic properties. Indeed, some former brick and tile producers took advantage of this by limiting their quarry excavations to the upper few metres of weathered shale.

Lime content is highest near the middle of the formation, and other small mineral and chemical variations are traceable from top to bottom of the Queenston Shale section.[1] Lime content also increases northward, and on Manitoulin Island the formation is represented by limestone and dolostone.

Queenston Shale has barely sufficient plasticity for brick and tile extruders. Plasticity is improved by natural weathering and fine grinding, and by minimizing the content of the more brittle green lenses. The firing range is short and the fired colour is normally salmon–red; both firing range and depth of colour is improved with weathered shale.

Expanded aggregate has not been made from Queenston Shale in Ontario, although some shale sections have fairly good bloating characteristics. However, bloating takes place almost at the point of fusion, making it poorly suited for the production of coated aggregate in the rotary kiln,

Two unique but thin deposits of red clay at Burlington and Hamilton were formed exclusively from weathered Queenston Shale originating from nearby eroding shale terraces. These deposits, much reduced in lime by leaching, were almost of stoneware quality, and were used extensively in the making of sewer pipes, flowerpots and other pottery products. While these deposits have now been depleted or lost to urbanization, weathered Queenston Shale, whenever it can be obtained, is still used as a major constituent of various pottery and artware products. Its preparation after excavation may involve years of further natural weathering, followed by blunging and filter–pressing.

The results of chemical, mineralogical and ceramic testing of numerous channel samples from quarry faces active in 1961 are given in a previous report.[1] Testing of several samples from Owen Sound has also been previously reported,[2] clearly showing the sharp increase in lime content of the more northerly shale exposures.

Average composition and ceramic properties of Queenston Shale are given in Tables 2.5 and 2.6, along with data for typical weathered shale. New test results for samples from Collingwood, Creemore, Huttonville and Georgetown are reproduced in Tables 2.5 and 2.7.

Arkona Formation

The Arkona Formation consists of soft, easily weathered, grey shale which, despite a tendency for significant scumming and efflorescence, is proving to be an important raw material for heavy clay products. Its occurrence in Ontario is restricted to the southwest where it is used for making drainage tile at Parkhill and flue liners at St. Thomas. It was formerly used also for bricks at Parkhill and drainage tile at Thedford.

The Arkona Formation is part of the Hamilton Group of limestones and shales of Middle Devonian age. The Hamilton Group comprises six formations as outlined in Table 2.8. Previous descriptions[1] of the shale exposures in two quarries at Thedford and Arkona put the shale in the Petrolia Member, now the Widder Formation, but these shales are now given formation status and placed lower in the geological record.

The area in which the Hamilton Group occurs in southwestern Ontario is shown on Figure 2.2. Scarcity of exposures makes it impossible to deline-

TABLE 2.8 SUBDIVISION OF THE HAMILTON GROUP.

Formation	General Lithology
Ipperwash	Upper limestone
Widder	Calcareous fossiliferous shale
Hungry Hollow	Pyrite crinoidal limestone
Arkona	Soft grey shale
Rockport Quarry	Limestone
Bell	Lower shale

ate the Arkona Formation specifically. The best exposures of Arkona Shale are in the banks of the Ausable River east of Arkona at Hungry Hollow (Photo 2.2), and Decker Creek north of Thedford.

While the Thedford quarry is now inactive, two Hungry Hollow quarries near Arkona are supplying all the raw material for drainage tile at Parkhill and part of the raw material for flue liners at St. Thomas. Amos C. Martin Limited established the "South Pit" (Photo 2.2, bottom) on the south bank of the Ausable River at Hungry Hollow in 1968. It is in lot 22, concession VII, West Williams Township, Middlesex County. In 1979 Martin also acquired the "North Pit", on the north bank in lots 22 and 23, concession IX, which had been worked by Parkhill Brick Company from 1963 to 1979.

The geological section exposed in the North Pit is described in a previous volume.[1] In the South Pit about 9 m of soft shale is exposed beneath 1.5 to 2 m of Hungry Hollow pyritic crinoidal limestone and several metres of Widder calcareous, fossiliferous shale. A single vertical drillhole has proved the Arkona Shale to be 43.5 m thick at this point. The shale is uniformly grey, soft, thin bedded but massive in appearance, sparsely fossiliferous, weakly calcareous, and easily weathered to clay. Local rusty staining originates from the overlying pyritic limestone beds.

Test results from previous sampling of the North Pit are reproduced in Tables 2.9 and 2.10.

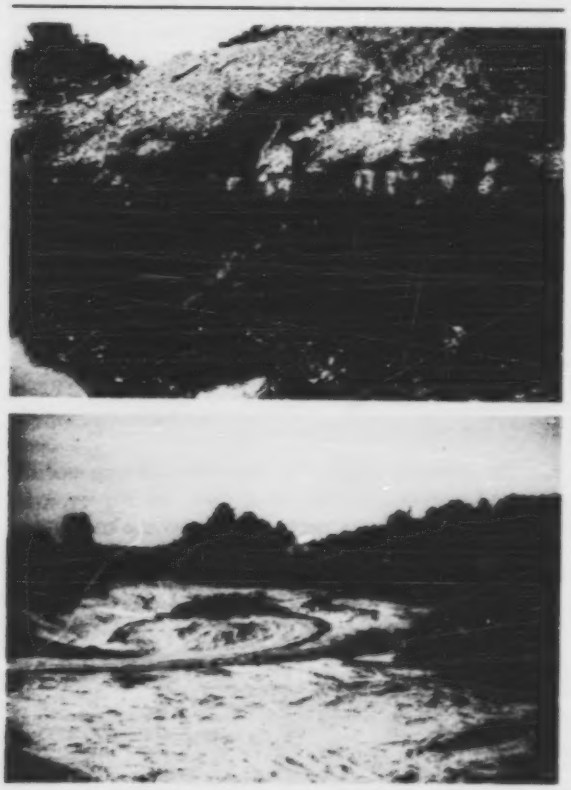

Photo 2.2 Top: Soft Arkona Shale at Hungry Hollow. Bottom: South pit in Arkona Shale, Amos C. Martin Ltd. Photo courtesy B.H. Feenstra.

SHALE RESOURCES

In 1978 the Clay Brick Association of Canada sponsored a study[7] to delineate the shale resources of Ontario. Of particular interest were areas where the Queenston, Georgian Bay, Blue Mountain and Arkona shales were not excessively covered by overburden. Using water well records as a guide to overburden thickness, areas covered by not more than 7.6 m of glacial drift were outlined within the known shale outcrop belts. Part of south–central Ontario had been previously researched by Vos[8] who attempted to define potential sources of both clay and shale.

While the shale formations of principal interest for brickmaking are known to be thick, common quarrying practice is inclined toward relatively shallow excavations. Hence, in making reserve calculations in the areas defined as favourable in terms of overburden thickness, a shale depth of 7.6 m was

TABLE 2.9 ARKONA SHALE, ANALYTICAL DATA.(1)

Chemical Composition* (percent)

SiO_2	51.96
Al_2O_3	18.1
Fe_2O_3	6.40
CaO	6.48
MgO	2.45
Na_2O	0.21
K_2O	3.82
TiO_2	0.89
CO_2	5.36
H_2O+	3.95
H_2O-	0.70
SO_3	0.50
Total	100.8
Soluble Salts	0.66
Ignition Loss	9.74

Mineral Composition* (percent)

	Percent
Quartz	27
Calcite	9
Dolomite	<0.5
Na/Ca Feldspar	<0.5
Potash Feldspar	<0.5
Clay Minerals	62
Illite	Abundant
Chlorite	Abundant
Expanding minerals	Trace

*5 m section exposed in A. C. Martin's north pit

TABLE 2.10 ARKONA SHALE, CERAMIC PROPERTIES.(1)

	Upper 1.5 m*			Lower 3.5 m*		
Water of plasticity, %		25			25	
Drying shrinkage, %		4.3			4.3	
PCE		6			6	
Firing temp., °C	900	1000	1080	900	1000	1080
Cone	010	06	03	010	06	03
Fired shrinkage, %	0	3.5	5.2	0	1.7	2.6
Water absorption						
24 hr. cold, %	15	7.9	3.6	15.4	10.1	6.3
5 hr. boiling, %	15.5	8.3	3.9	16.1	11.1	6.7
Specific gravity	1.78	1.99	2.11	1.77	1.87	1.94
Colour	brown → dark brown			brown → rust brown		
Hardness	hard → very hard			hard → very hard		
Remarks	abundant white scum; overfired					

*5 m section exposed in A. C. Martin's north pit

TABLE 2.11 POTENTIALLY AVAILABLE RESERVES OF SUITABLE SHALE IN ONTARIO.(8)

County/Region	Geographic Township	Net Reserves Millions of Tonnes	Hectares
Dufferin	Mono	22	134
	Mulmur	125	765
Halton	Esquesing	161	981
	E. Flamborough	113	688
	Nelson	142	870
	Trafalgar	260	1,568
Niagara	Clinton	128	783
	North Grimsby	71	431
	Niagara	4	28
Peel	Albion	30	182
	Caledon	14	83
	Chinguacousy	567	3,468
	Toronto	26	162
	Toronto Gore	179	1,093
Russell	Russell	166	1,012
Simcoe	Nottawasaga	260	1,590
Hamilton-Wentworth	Saltfleet (now Town of Stoney Creek)	122	749
TOTAL		2,390	14,605

considered. A bulk density of 2.24 tonnes/m^3 was taken to be representative of the unbroken shale in place; this is approximately equivalent to 171,751 tonnes per hectare to a depth of 7.6 m.

Calculated tonnages were reduced by 25 percent to allow for elimination of waste rock and other quarry losses. Reserves are listed by township in Table 2.11, totalling 2,390 million tonnes within areas totalling 14,605 hectares. Except for an area in Russell Township near Ottawa, these reserves are restricted to the Niagara Escarpment and lands marginal to it on the east (Figure 2.3).

It has been estimated that 3.4 tonnes of shale are consumed in the making of 1,000 bricks. Hence, about 1.5 million tonnes of shales, equivalent to 9 hectares of shale lands, are consumed annually in Ontario at current levels of production. While there is no apparent physical scarcity of shale, it must be remembered that these reserves are not evenly distributed about the province, and that their predominance in the densely populated Toronto–Hamilton area puts in jeopardy their availability for future use. Indeed, these are gross calculations which have not been discounted for urbanization, conflicting land uses, environmental restric-

Figure 2.3 Principal shale resource areas of southern Ontario.

tions, restrictive legislation and local quality limitations. Even without all the restrictions imposed by urbanization, the lack of physical testing is a major weakness in making shale reserve calculations. Brittle shale, local concentrations of hard limey layers, and erratic distribution of gypsum and other soluble salts are only some of the unpredictable features that can cause the elimination of some shale locations from economic use.

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Chapter 3 — Kaolin Clays of Ontario

INTRODUCTION

Kaolin (also known as china clay), is a platey mineral composed of stacked sheets of a silicate–gibbsite bi–layer. Bonding within the bi–layer is strong with only weak attraction between the sheets. The structure of the clay gives it a 'greasy' feel when wet and highly plastic behaviour. When kaolinite is pure, with very little substitution of aluminum and silicon in the structure, it is very refractory and fires to a pure white colour. Extensive substitution by iron, magnesium and titanium results in "fireclay". The degree of substitution in a clay influences its surface properties and thereby affects the rheological properties. It also influences the colour of the clay (both before and after firing), its refractoriness and its performance as a filler material.

Clays find a multitude of uses in modern industrial technology, the most well known being those in ceramics where they act as not only the prime structural components, but also as a pigment and a binder. Such products find applications which range from conventional bricks and pottery to high–temperature–resistant refractories and highly sophisticated specialty components.

In recent years, however, the traditional ceramics market for prepared clays has been supplanted by its use as a filler/extender material. Such applications make use of the platey crystal structure, natural binding action, high reflectivity and opacifying properties. In addition, the common occurrence of clay minerals ensures that they are relatively inexpensive which, although not a technical requirement, is often considered to be highly desirable.

In the ceramics industry kaolin is used in the manufacture of bone china, porcelain, stoneware, whiteware, sanitaryware, electrical insulators, and refractories and refractory aggregate. To meet the requirements of high refractoriness and white colour on firing the clay must be mineralogically and chemically pure. It must also possess suitable plasticity and rheological properties for moulding or slip casting behaviour in industrial forming processes.

Another major industrial use of kaolin is in the paper industry. Kaolin finds use in coatings for high gloss finish paper and as a filler material to produce opacity in the paper. The requirements of the clay in this application are that it be very white and have a high reflectance (brightness) value, greater than 90% for paper coating and ~85% for filler. The rheological properties of the clay are also important. The industry has determined that for an ideal coating clay a slurry of ~70 weight percent solids has rheological properties suitable for paper coating applications.

Kaolin is also used as a filler in the rubber industry for reinforcing or stiffening the rubber or as a low cost rubber pigment. It is used in abrasives, plastics and paints as a filler or extender and as a carrying agent for pesticide dusting operations.

Generally, the governing factors for determining the suitability of a kaolin clay for the above described applications are:

1. Chemical and mineralogical purity,
2. Crystallinity,
3. Particle size distribution.

The kaolin clay used by Canadian industries is imported, mainly from the U.S.A. and the United Kingdom. In 1984 Canada imported over 250,000 tonnes of china clay and approximately 50,000 tonnes of fireclay. This is in contrast to Canada's total raw clay exports of 646 tonnes. The consumption of kaolin and fireclay by the Canadian industry is given in Table 3.1, taken from the yearly review of Clays and Clay Products by the Department of Energy, Mines and Resources.[10]

The only significant deposits of kaolin clay found in Ontario are in the region of the James Bay watershed, specifically in the Moose River Basin. Extensive deposits of kaolin–silica sand mixtures have been found along the Missinaibi and Mattagami Rivers. The difficult terrain and climate of northern Ontario and distance from markets have restricted development of these deposits. However, programs have been undertaken to explore these deposits and assess their industrial potential, and the results obtained appear encouraging.

Exploration of phosphate deposits associated with carbonatite complexes in Cargill Township, south of Kapuskasing, and at Martison Lake north of Hearst, has also revealed some kaolin clay sequences similar to those of the Moose River Basin, apparently protected from glacial removal by the topography.

TABLE 3.1 CANADA, CONSUMPTION (AVAILABLE DATA) OF CLAYS, BY INDUSTRIES, 1981–1984. (10)

	1981	1982	1983P	1984P[1]
		(tonnes)		
China Clay				
Pulp and paper products[2]	85,555	92,997†	97,235	146,689
Ceramic products	9,764	6,680	10,267	9,378
Paint and varnish	5,955	5,510	6,082	5,705
Rubber and linoleum	4,033	5,951	6,568	7,225
Other products[3]	21,917	74,513	21,176	21,660
Total	127,224	185,651†	141,328	190,657
Ball Clay				
Ceramic products misc.	18,694	11,084	19,749	16,506
Refractories	2,743	11,969	2,578	2,280
Other[4]	127,979	78,951	45,049	51,084
Total	149,416	102,004	67,376	69,870
Fire Clay				
Foundries	11,731	8,936	8,829	9,857
Refractories	14,929	14,546	5,840	6,803
Other[5]	2,467	4,183	9,458	11,383
Total	29,127	27,665	24,127	28,043

1. Increase in number of paper and paper products and paper pulp companies surveyed.
2. Includes paper and paper products and paper pulp.
3. Includes refractory brick mixes, cements, glass fibre and wools, adhesives, foundry, wire and cable and other miscellaneous products.
4. Includes structural clay products, adhesives, miscellaneous chemicals, petroleum refining, paint and varnish and other miscellaneous products.
5. Includes abrasives, ceramic products, concrete products, paint and varnish, petroleum refining, and rubber products.

P Preliminary
† Revised.

MOOSE RIVER DEPOSITS

Geology

Kaolin clays and quartz sands of Mesozoic age occur over an area of some 10,000 km² in northeastern Ontario (Figure 3.1). They form a wedge of unconsolidated continental sediments that have been gouged and disturbed by Pleistocene glaciers but were saved from complete removal by deflection of the ice over an upland area of Precambrian rocks that form their southern margin. They rest largely on Devonian shale and limestone of the Moose River Basin, and are covered by a thick sequence of glacial till, marine clay, sand, and muskeg. Access is difficult and exposures are few, but programs of deep drilling sponsored by the Ontario Government since 1975 have provided much useful information on the character and distribution of kaolin, fireclay, quartz sand and lignite.

The Mesozoic sediments of the Moose River Basin are mostly Lower Cretaceous in age, although a thin unit of Middle Jurassic age has been recognized in a few drillholes. The Cretaceous sediments comprise thick sequences of kaolinitic quartz sand interlayered with lenses of refractory clay and lignite, all belonging to the Mattagami Formation. The Mistuskwia Beds of Middle Jurassic age consist of varicoloured calcareous clays and thin horizons of fine- to medium-grained, calcareous and well-rounded quartz sands.[14]

The Mattagami Formation is of particular economic interest because it contains the only sizeable occurrences of lignite, kaolin and refractory clay in Ontario. The formation contains two distinct phases (Figure 3.2): an early phase characterized by lignite and much black carbonaceous clay (Type A); and a subsequent phase consisting predominantly of thick sequences of white kaolinitic quartz sand and light-coloured, non-calcareous clay (Type B).

A Precambrian ridge known as the Grand Rapids Arch may have formed a barrier to the deposition further north of the younger light-coloured Type B sediments which contain the most attractive kaolin. North of the arch, in the Onakawana area, grey and black carbonaceous clays, some of fireclay quality, predominate with lignite. Type A sediments also occur at depth south of the arch where they are overlain by thick sequences of Type B sediments.

The Cretaceous sediments were deposited in a shallow fresh-water lake at the foot of the Precambrian escarpment that formed its southern shore about 100 million years ago. The origin of the kao-

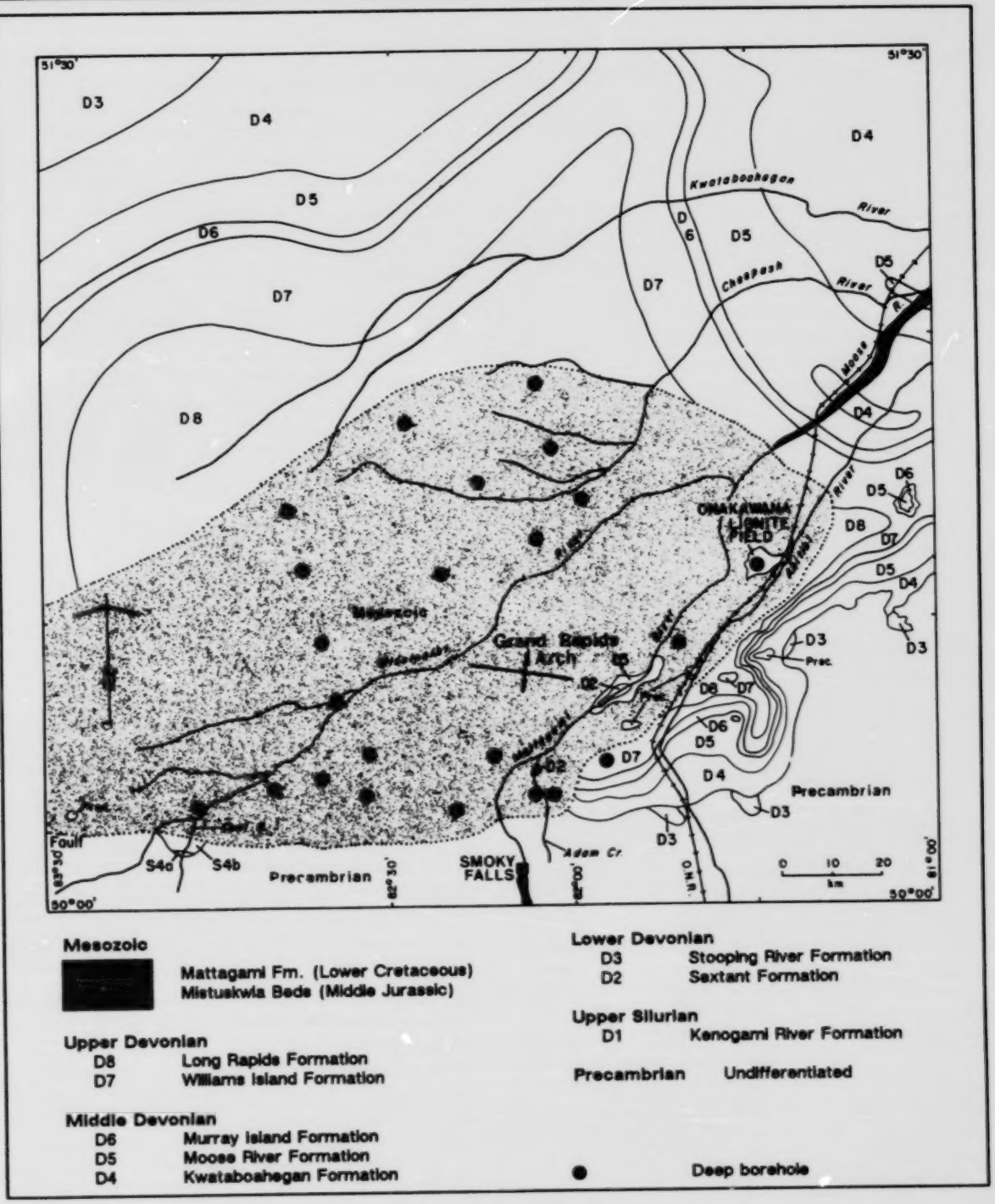

Figure 3.1 Geology of the Moose River Basin[14]

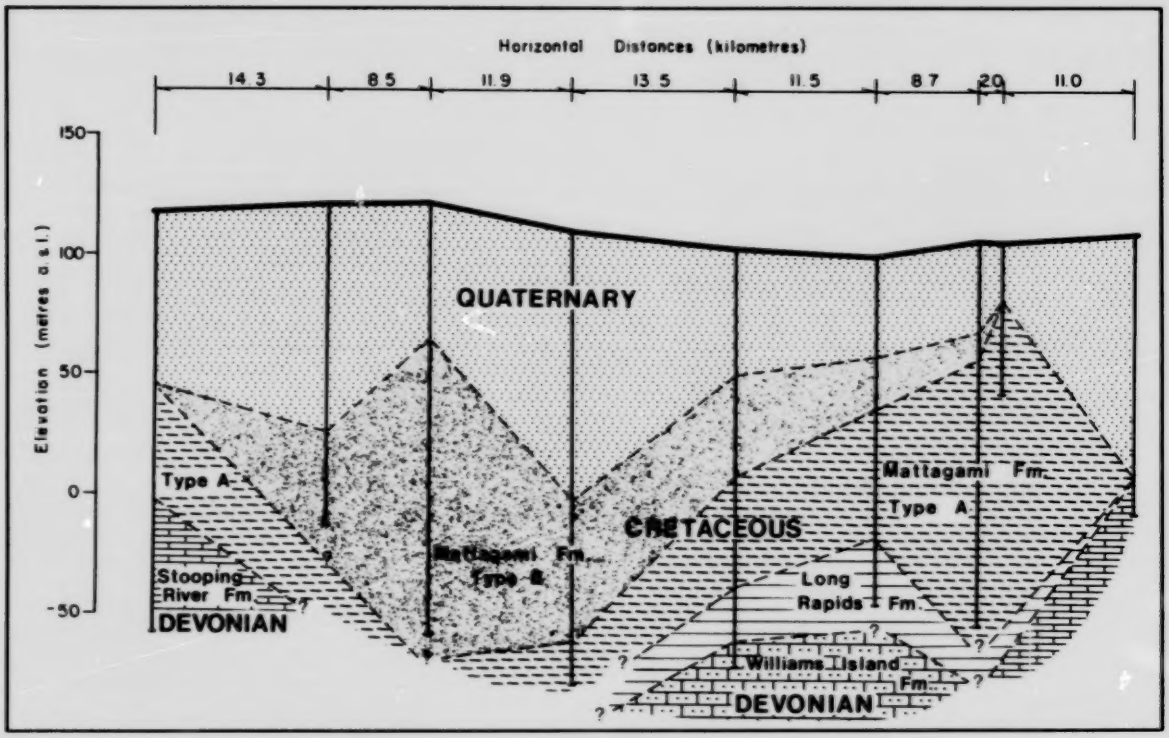

Figure 3.2 East–west section through the Moose River Basin.[4]

lin is believed to have been in the weathering of feldspars in the predominantly granitic rocks of the Precambrian highlands. Streams flowing off the highlands carried the weathered products into the Cretaceous lake that occupied the Moose River Basin at that time. Much of the clay may have remained in suspension in the lake waters, and only in periods of extreme dryness when the waters evaporated was the clay deposited in thick horizontal lenses and beds.

Exposures of plastic clay are scarce, as are the beds of kaolinitic sand and lenses of lignite, but drilling has proved their persistence over a wide area beneath heavy overburden. Only in a few deeply cut river banks along the Mattagami and Missinaibi Rivers and their tributaries can these clays and sands be seen at times of low water.

It is believed that the Mesozoic sediments overlie a 600 m sequence of nearly flat Paleozoic rocks of Silurian and Devonian age. These are mainly limestones, shales and evaporites of marine origin. Devonian stratigraphy in the area is described by Sanford and Norris.[11]

Quaternary sediments cover the Mesozoic in thicknesses up to 100 m or more. These consist of several till sheets intercalated with non–glacial silts, clays, sands, gravels and peaty sediments, all with a uniform capping of muskeg. The Quaternary is thoroughly described by Skinner.[12]

The area of principal interest extends for 80 km along the east–west Precambrian escarpment that forms the southern limit of the basin. Sporadic drilling has shown that the deposits extend up to 40 km northward from the escarpment.

The southern edge of the basin is accessible by road from Fraserdale and Kapuskasing. The eastern limit of the kaolin area is 15 km west of Coral Rapids on the Ontario Northland Railway. Access to the western part of the basin is restricted to lumber roads north from Hearst, from which final access must be by winter road.

Kaolin

Kaolin of possible commercial significance occurs as a white matrix between the quartz grains in the thick beds of quartz sand that comprise much of the Type B unit.[5] Horizontal lenticular beds of white and brightly–coloured plastic clay are also common.

They consist almost entirely of kaolinite, and are generally highly refractory.

The kaolin–quartz sand sequence is water–saturated, and much of the fine white kaolin is mobilized in suspension throughout the sand beds, giving rise to kaolin–rich and kaolin–poor horizons. Kaolin–rich layers may contain as much as 20 percent or more of kaolinite. The possibility of mining these beds by a pumping technique using cased wells, and delivering the slurry by pipeline to a processing plant, has been examined in some detail and is considered feasible.[3]

A maximum thickness of 127 m has been recorded for the light–coloured Type B unit in a drillhole in the south–central part of the basin.[4] Kaolin–bearing sand horizons vary up to 20 m in uninterrupted thickness, but normally average 5 m to 10 m. Interbedded clay lenses are generally thinner.

While there has been some deep exploration drilling by private interests, most field studies have been directed towards the few Cretaceous outcrops in deeply cut river channels. However, much of our present knowledge of these deposits has resulted from deep drilling programs by the Ontario Government in recent years.

Processing requirements and filler markets for kaolin have been recently documented.[6]

Ceramic Refractory Clays

Dense plastic clays of various colours form a large part of the Cretaceous section, interlayered with kaolin–bearing quartz sands in the Moose River Basin. Many are highly refractory and suitable as fireclays in high temperature applications. Others are typical ball clays and stoneware clays, suitable for whiteware, china and pottery, sewer pipe and building bricks.

Deep drillholes have proved the widespread distribution of these clays. But, more importantly, there are several locations where they are reasonably accessible, in particular at the foot of the Kipling dam in Kipling Township. Here clays can be dug from the east bank of the Mattagami River at times of low water, and a thick deposit is known beneath shallow overburden on the west side, accessible by road.

Clays of these qualities are known nowhere else in Ontario. Similar clays are imported largely from Ohio and Pennsylvania, along with many ceramic and refractory products which might otherwise be made locally. However, even if they were readily accessible, transportation costs from northeastern Ontario to markets in southern Ontario would impose a considerable economic constraint.

Plastic kaolinitic clays of fireclay, ball clay and stoneware quality occur in large quantities and various qualities with lignite at Onakawana. About 10 million tonnes is estimated to overlie the upper lignite bed.[15] In any quarrying operation for lignite, these clays would have to be moved. They are a valuable resource, found nowhere else in Ontario, and as much as possible should be utilized or stockpiled. In doing so, care should be taken to keep the various qualities separate. Clays associated with lignite belong to the Type A unit of the Mattagami Formation. They are typically dark grey to black because of an abundance of organic carbon, but some become white or nearly white on firing.

For easy accessibility, the clays below the Kipling dam on the Mattagami River are of particular interest. Thin beds of white, brown, red and olive grey plastic clay can be seen at intervals along the east bank, particularly at low water. These are privately owned lands which have undergone numerous testing studies over the years by various companies primarily interested in kaolin.

A good thickness of variously coloured plastic clays also occurs on the west bank beneath shallow overburden. An old overgrown pit marks the site of an early attempt at commercial production. Removal of further dense clay till overburden for use in the core of the Kipling dam makes this deposit more accessible, though still largely unexposed.

In general, all the Cretaceous clays are smooth and plastic, and composed of kaolinite, fine quartz and minor illite. Many are highly refractory, with pyrometric cone equivalents in excess of 30, and alumina contents greater than 30 per cent. Maximum recorded PCE was 36, and alumina content 38.7 percent.

The firing characteristics for numerous samples taken throughout the Moose River Basin by a number of early workers have been tabulated by Vos.[14] These illustrate the great variety of clays available in terms of PCE and colour, both in the fired and natural state. Many dark grey to black clays fire to a nearly white colour as their carbon is burned off.

White burning clays are preferred for most ceramic uses, and, if of superior quality, might find application in the making of fine china, sanitaryware and other whitewares. Clays that fire to cream colours, or buff, grey, pink or red can find use in the making of building bricks and sewer pipe, in refractory mixes and bricks, and in pottery and stoneware.

For some of these uses, less refractory (i.e. lower PCE) clays are preferred; otherwise very high firing temperatures are required. (The fired ware could be too porous and soft at lower conventional firing temperatures.) In some cases too, blunging and wet screening of the clay may be necessary to remove traces of sand grit, mica and iron–bearing minerals, some of which may otherwise result in an unattractive speckled surface after firing.

With the exception of the high volume brick and refractory brick industry, clays are seldom used as the sole ingredient of the ceramic composition. Usually a blend of clays and/or other silicate (non–plastic) ingredients, such as feldspar and flint, are used to produce a fired product of desired properties. (In the case of ceramics, it is the chemical, physical and high temperature properties which determine their application.)

The most important properties of ceramic clays are:

- mineral composition,
- chemical composition (impurities),
- plasticity (formability),
- deflocculation characteristics (for preparation of slips),
- particle size distribution,
- drying shrinkage,
- refractoriness (fusion point),
- vitrification range or firing range,
- fired colour,
- fired properties: absorption; shrinkage; strength; thermal expansion.

LABORATORY TESTING OF KAOLIN

The clay deposits of the Moose River basin have been explored as possible sources of high grade kaolin. Analyses of the deposits have been performed to determine their physical and chemical properties and to assess their commercial potential. Most of this work has been aimed at high volume paper and filler applications, but some evaluations have been conducted to determine ceramic properties.

MISSINAIBI RIVER DEPOSIT

In the late 1960s Algocen Mines Limited obtained an Exploratory Licence of Occupation for a 23,000 ha region along the Missinaibi River from McBrien through Habel Townships in the District of Cochrane. A plan of this licence is shown in Figure 3.3. Indicated on the figure are the locations of three deposits explored as potential sources of kaolin clay.

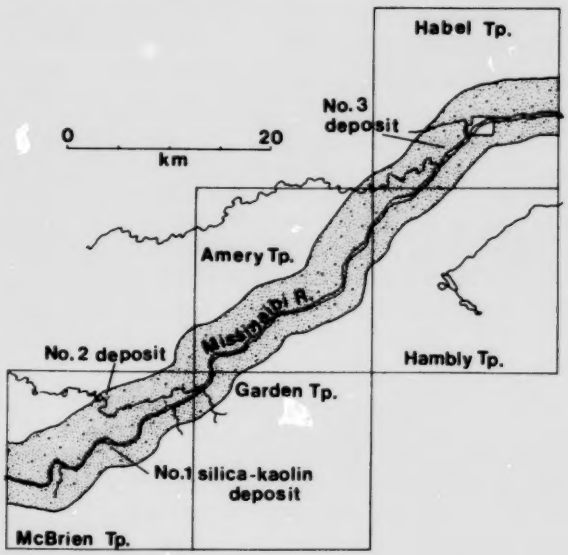

Figure 3.3 Algocen Mines Exploratory Licence of Occupation along the Missinaibi River.[13]

The kaolin of these deposits is associated with varying amounts of coarse sand and lenses of fireclay. A cross–section of one of the deposits is depicted in Figure 3.4. The kaolin content of the sand–clay deposit is estimated at approximately 20%. Clay–rich lenses in the deposit contain up to 50% kaolin.

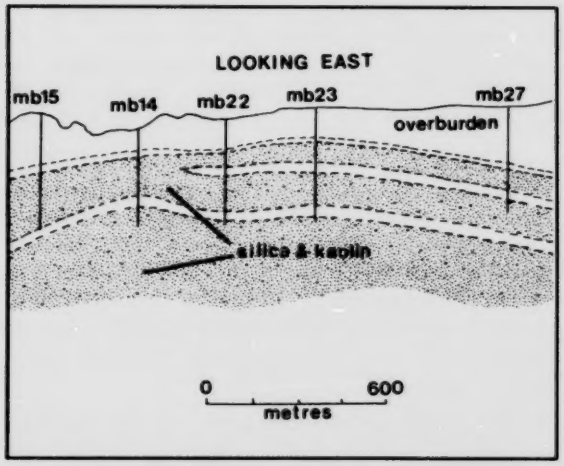

Figure 3.4 Typical cross–section of kaolin clay – sand deposit along Missinaibi River.[13]

Raw Material Testing

The sand fraction of the Missinaibi clay deposit may be readily separated from the bulk material by attrition washing and screening, further beneficiation can be achieved by flotation and/or high intensity magnetic separation. The sand fraction is essentially coarse grains, and the size distribution varies somewhat across the deposit; however, blending of different screen fractions to produce a composite suitable for commercial glass melting applications will produce a high grade glass sand. A typical chemical analysis of a beneficiated, floated and/or magnetically cleaned glass sand is given in Table 3.2.

The quality of the sand fraction is comparable to material currently being used in glass manufacture.

X–ray analysis indicates that a quantity of quartz, ~5.0%, remains in the –325 mesh material which is essentially kaolin clay. Further beneficiation to –10 μm and –2 μm particle size lowers the quartz content to ~4% and 1% respectively, the values varying slightly across the deposit. The –325 mesh clay fraction also contains small amounts of muscovite mica, illite, a magnetic ilmenite–type material, and some amorphous material.

Size separation of the clay from the associated impurities in the fine fraction can be effected on a commercial scale by hydrocycloning or centrifugal techniques. Iron–bearing components in the clay that give it a dark colour generally are not removed by size fractioning alone. Flotation techniques or magnetic separation may also be necessary to reduce the quantity of these contaminants in the clay.

The kaolin of the clay deposit is well crystallized, the crystals being well separated and hexagonal in shape. An electron micrograph of the clay particles is shown in Photo 3.1. The edges of some of the crystals have a rough appearance due to the adherence of small particles, possibly colloidal alumino–silicate material. Beneficiation procedures to remove such contamination were never conducted.

TABLE 3.2 CHEMICAL COMPOSITION OF BENEFICIATED GLASS SAND FRACTION FROM MISSINAIBI RIVER DEPOSIT.(7)

Component	Percent
SiO_2	99.68
Fe_2O_3	0.014
Al_2O_3	0.125
TiO_2	0.009
CaO	0.0004
MgO	0.003
K_2O	0.002
Na_2O	0.003
P_2O_5	0.004
L.O.I.	0.18

Photo 3.1 Electron micrograph of kaolin from the Missinaibi River deposit.[9]

X–ray differential thermal analysis has indicated the clay to be of the kaolin type, but with a slight disorder.

Forming/Fabrication Testing

Tests were performed on samples of clay from the Missinaibi River deposits to assess the potential of the clay for commercial use. Essentially, the experiments were aimed at applications in the paper and mineral filler industries. Minimal information is available on ceramic properties.

The paper industry is North America's major consumer of kaolin. In this application the rheological properties and brightness of the clay are governing factors for use.

Beneficiated clay brightness values indicated that the Missinaibi kaolin is unlikely to meet the grade for paper coating without significant improvements in beneficiation technology. Property measurements do show that the kaolin may be suited for use as paper filler. Tests have been performed on the clay which indicate that the clay is free of grit, equal in abrasiveness to an English clay currently used in the industry and produces paper with 10% higher retention, higher opacity, equal smoothness, and 10–100% higher densometry (inverse air permeability).

Under small scale testing Missinaibi kaolin was also found to be suitable for use in rubber, with behaviour similar to a commonly used North Carolina clay.

From a ceramic point of view, the clay is a very plastic fine grained material with low sensitivity to water content. The pyrometric cone equivalent is cone 34; pure kaolin has a refractoriness of cone 35. The −325 mesh fraction of the clay deposit fires to a cream–white colour. The fired colour for the −10 μm and −2 μm size fraction is grey–white. Firing shrinkage of such fractions of the clay is high, suggesting that it may be more suitable for ceramics or refractories in a calcined form. (The material compared well with commercial calcined kaolin aggregates used in high alumina refractory production.)

Brady and Dean[1] also studied the potential of a Missinaibi clay deposit. This deposit is located in Burstall Township along the Missinaibi River and borders the exploratory licence of Algocen. Analysis of this clay showed that it consists mainly of kaolin and quartz, 62% and 22% respectively. Similar to the other Missinaibi deposits, the clay is very plastic with high firing shrinkages of the order of 12%. The clay could probably be used as refractory grog after pre–firing. The clay fires at PCE ~30–32, to a creamish buff colour or speckled brown.

MATTAGAMI RIVER

The kaolin deposits of the Mattagami River, are very similar to those of the Missinaibi, and consist of coarse silica in a fine clay matrix. The kaolin content has been estimated at less than 20%. The clay–rich sections of the deposit are predominantly discoloured fireclay.

Fractionation of the material by attrition scrubbing and sieving through a 325 mesh screen yields +325 fraction of white sand with a few black specks which are a magnetic ilmenite–related mineral and, −325 fraction of clay containing impurities in the form of fine silica, mica and additional ilmenite–type mineral.

The −325 mesh material contains approximately 90% below 10 μm particle size. Chemical analysis of −10 μm material shows little alkali or organics. A complete analysis is given in Table 3.3. Electron micrographs, Photo 3.2, show the kaolin to be well formed hexagonal crystals. These samples had been subjected to high shear mixing and, as a result, appeared free of colloidal contamination. The material is also low in MnO_2, a requirement for use of the clay as filler in rubber.

TABLE 3.3 COMPARATIVE ANALYSIS OF NORTHERN ONTARIO KAOLINS.

	Missinaibi River(9) Deposit (−2 μm fraction)	Mattagami River(7) Deposit (−10 μm fraction)	Theoretically Pure Kaolinite(2)	Georgia Kaolin(2)
Chemical Analysis (%)				
Loss on Drying at 105°C	0.86	1.0		
Loss on Ignition (after drying)	13.81	13.18	13.96	13.49
Silica	45.25	48.33	46.54	45.0
Alumina	37.75	37.75	39.50	38.60
Iron Oxide (Fe_2O_3)	0.98	0.93		0.36
Titanium Oxide (TiO_2)	0.63	0.27		1.60
Manganese Oxide (MnO)	0.004	0.014		
Calcium Oxide (CaO)	0.20	0.16		0.14
Magnesium Oxide (MgO)	0.10	0.16		0.13
Potassium Oxide (K_2O)	0.07	0.26		0.18
Sodium Oxide (Na_20)	0.06	0.04		0.06
Organic Carbon	0.08	0.18		
Mineralogical Analysis (%)				
Clay Mineral	95.03	88.0	100	97.4
Quartz	0.83	6.7		0
Mica	1.33	2.7		1.90
Fe_2O_3	0.99	0.93		
TiO_2	0.64	0.27		
CaO	0.20	0.16		
MgO	0.10	0.16		
Organic Matter	0.82	1.06		
Pyrometric Cone Equivalent	34	30–32	35	34–35

The brightness and rheological properties of the clay were determined to assess the potential for use in the paper industry. As in the case of the Missinaibi deposit, material which could be beneficiated to the level required for coating applications was not found, however beneficiation was able to improve the material to a level which borders on the requirements for paper filler. The rheological properties of the clay also eliminates it for use as coating grade clay. Great difficulty was experienced in developing good flowing slurries at concentrations in excess of 60% solids.

The clay after washing ranges from buff to white in colour. Fired to 1150–1200°C, the clay is white suggesting possible whiteware/stoneware applications.

LABORATORY TESTING OF FIRECLAYS

While the majority of clays located in the James Bay Lowlands are white kaolin clays, other cream, red, green, tan, grey and black coloured clay seams are also to be found. These coloured materials are usually referred to as fireclays locally.

X–ray diffraction analysis of the –325 mesh fraction of some of these raw materials (Figure 3.5) indicates that they are virtually all similar, whether they are white, grey, cream, red or tan coloured. Of the samples evaluated, only the green clay appears different, due principally to the presence of bentonite and illite. Chemical analyses of the clays are given in Table 3.4. (These particular samples were obtained from the Mattagami River banks.)

Examination of white and red clays more closely (Figure 3.6) indicates similar curves, and suggests that the clay's minerals are identical except in colour (accessory mineral proportions probably vary because of the broad grain size distribution of the samples). Mineralogical analyses of the red and white fireclay (Table 3.5) indicate high levels of quartz due to the coarseness of the sample fraction, and also indicate that hematite is a major impurity.

Plasticity measurements of the white and red fireclays were performed; the curves obtained are given in Figure 3.7.

The white fireclay shows good plasticity, the curve being smoothly rounded and having an amply

Photo 3.2 Electron micrograph of kaolin from the Mattagami River deposit. [9]

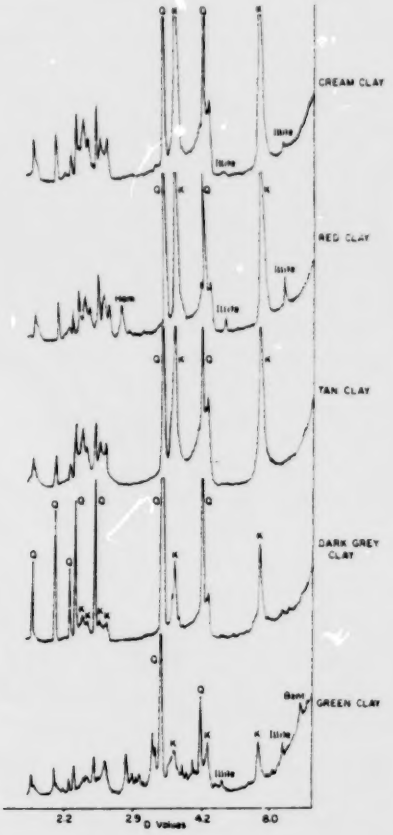

Figure 3.5 X–ray diffraction analyses of assorted northern Ontario clays. [8]

TABLE 3.4 CHEMICAL ANALYSES OF NORTHERN ONTARIO CLAY SAMPLES. (8)

Major Oxide	White Fireclay	Red Fireclay	Tan Brown Clay	Red Clay	Olive Green Clay	Dark Grey Clay	Cream Clay
SiO_2	56.24	56.60	55.35	55.04	59.90	72.28	56.57
Al_2O_3	29.20	25.71	29.14	25.15	17.59	17.84	29.50
Fe_2O_3	1.58	6.63	1.58	7.98	7.18	0.76	1.43
CaO	0.13	0.13	0.20	0.12	1.46	0.09	0.12
MgO	0.17	0.18	0.13	0.17	2.13	0.09	0.17
Na_2O	0.04	0.05	0.05	0.04	0.68	0.03	0.04
K_2O	0.26	0.38	0.10	0.42	2.77	0.13	0.34
TiO_2	1.32	1.21	1.37	1.17	0.78	1.39	1.33
L.O.I.	10.57	8.82	10.78	9.33	7.25	5.82	10.24

TABLE 3.5 MINERALOGICAL ANALYSES OF NORTHERN ONTARIO CLAYS BY X-RAY DIFFRACTION. (8)

Mineral Detected	White Fireclay	Red Fireclay	Tan Brown Clay	Red Clay	Olive Green Clay	Dark Grey Clay	Cream Clay
Kaolin	60–70	50–55	60–70	50–55	5–10	25–30	60–70
Quartz	25–30	25–30	25–30	25–30	20	60–70	25–30
Illite	<5	<5	<1	5	5	-	<5
Hematite	-	5	-	5–10	5–10	<1	-
Calcite	-	<5	-	<1	-	-	-
Unidentified	-	-	-	-	(chlorite bentonite vermiculite?)	-	-

wide plastic range. No forming problems are anticipated for this clay.

The red fireclay is highly plastic but has a high water of plasticity, ~32%. This could cause drying problems. The plasticity curve is distorted and sharpened, possibly indicating dilatency. This distortion is relatively minor and is not expected to cause problems except at unusually high shear rates.

The fired appearance and properties of clays, together with their refractoriness (or resistance to heat), is of course very important to their application. It is necessary that any products manufactured exhibit preferred *strength*, *shrinkage*, *absorption*, and *thermal expansion*, and also fire at the preferred temperature.

Gradient firings (i.e. firing of samples in a kiln with a controlled wide range of temperatures) indicate the kind of firing variations that one might get for a range of similar clays.

The application of gradient firings to the same clays previously described – i.e. cream, red, tan, grey and green – indicated how fired colour developed with temperature and how densification (or the ceramic reaction) progressed with increased firing temperatures.

It was shown that the tan, grey and cream clays become whiter with increasing firing temperature. It was also clear that at the maximum temperature used in the gradient firing of 1200°C, no significant degree of fusion had taken place for these samples.

However, in the case of the red clay, while complete fusion had yet to set in, the colour had become richer and deeper.

In the case of the green clay, it had obviously matured and fused at a low temperature ~1000°C, above which it had become molten and bloated.

Firing cubes of clays in the same way in a gradient furnace allows one to monitor the development of porosity and shrinkage with temperature. This can also be used as a guide to the degree of maturation of the ceramic, and hence the selection of a suitable firing temperature. Figure 3.8 shows how the development of porosity with firing temperature can be plotted for the red and white fireclays to provide information on the firing characteristics.

A gentle slope, as shown by the white clay, indicates a broad firing range which gives more flexibility and control on the finished product, while the steep slope shown by the red clay suggests shorter firing ranges and less flexibility and control.

Decreasing porosity and increasing shrinkage indicate the approach of optimum firing temperatures.

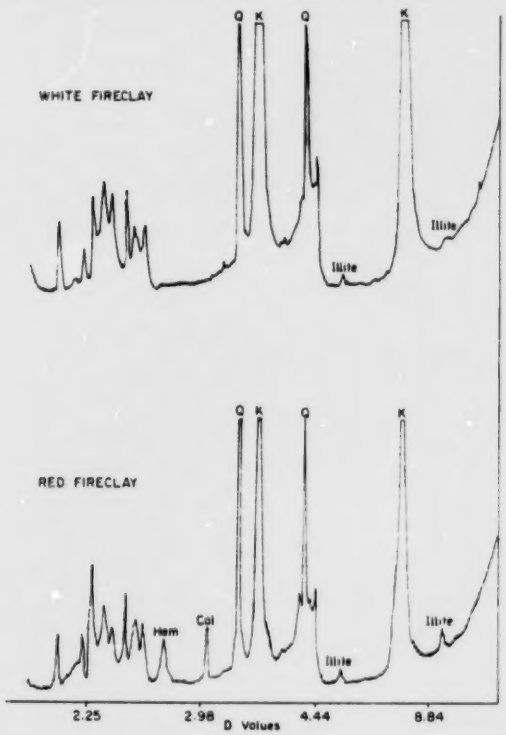

Figure 3.6 X-ray diffraction analyses of northern Ontario fireclays (unfired). [8]

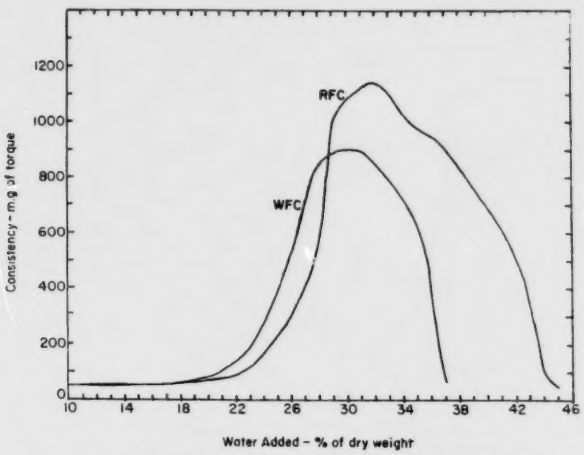

Figure 3.7 Plastigraph of northern Ontario fireclay. WFC = white fireclay; RFC = red fireclay.[8]

The gradient firing tests indicate that, in general, the northern Ontario clays are highly refractory, that is to say they melt or fuse at very high temperatures. The pyrometric cone equivalency test (P.C.E.) is a way of measuring the fusion temperature or ceramic clays by comparison with standard

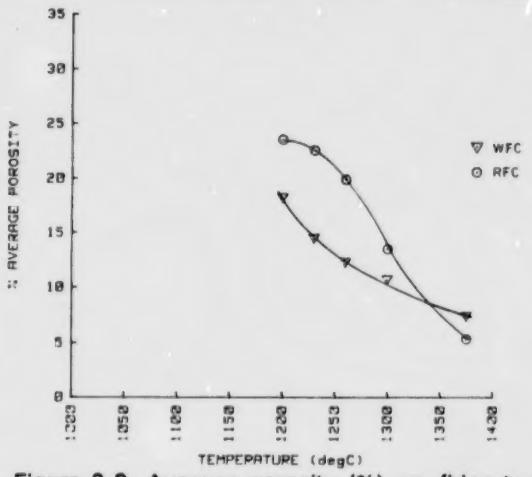

Figure 3.8 Average porosity (%) vs. firing temperature for northern Ontario fireclay. [8]

materials of known fusion temperatures and/or conditions.

Table 3.6 shows, amongst other data, a series of P.C.E. cone values for 5 of the clays discussed. It can be seen that the P.C.E. values vary from 04 to 31.

To put these into perspective:

04 ≡ ~1050°C	and is equivalent to earthenware firing temperatures
14 ≡ ~1250°C	and is equivalent to stoneware firing temperatures
19 ≡ ~1400°C	grades are considered to be
30 ≡ ~1500°C	refractory

Typically, the kaolin clays of this area are rated at cone 32, which means that most of the resources of this area can be considered to be refractory clays.

Given this information, we can consider that a major opportunity exists on a technical basis for the development of a refractory industry; maybe not in the form of refractory bricks, but possibly in the form of calcined refractory aggregate. For example, several companies take such clays, pelletize them and subsequently fire them to a high density. The resulting product is then ground to provide an aggregate. Such material is used as a source of alumina in high alumina bricks and as the refractory shell in investment casting. This is a high priced, value added product.

While fairly large experimental programs have been conducted on the kaolin clays of the James Bay Lowlands, the majority of the studies have concentrated on relative yields and possibilities for application in paper products. Very few studies have been conducted to evaluate the material as a ceram-

TABLE 3.6 PROPERTIES OF ASSORTED CLAYS.

Clay Sample	Moisture Content (%)	Drying Shrinkage (%)	PCE Cone (#)	Comments
Cream Clay	24.6	4.5	31	- White Firing Clay - Refractory - Low Firing Shrinkage
Red Brown Clay	25.5	6.5	19	- Fires Dark Brown, Mottled Streaks - Food Formability - Low Firing Shrinkage
Dark Grey Clay	14.7	1.0	30	- Approximately 90% Quartz - Little Kaolin - Little Clay Value
Olive Green Clay	28.8	7.8	04	- Little Kaolin, some Bentonite - Bloats after 1100°C - Little Clay Value
Tan Clay	24.5	4.0	14	- Cream Firing - Good Formability - Stoneware Clay - Moderate Shrinkage

ic resource. In the case of the "fireclay" zones, virtually no co–ordinated ceramic studies have been conducted. However, only minimal amounts of work have been done to date, and much more needs to be done to prove the quality of the resources as a ceramic raw material. Opportunities which have been discussed include:

- refractory applications
- firebrick
- pottery supply
- earthenware clays
- stoneware clays and clay blends
- cottage pottery industry.

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Part II — Heavy Clay Products

Chapter 4 — Brick in Ontario

HISTORY OF BRICK PRODUCTION IN ONTARIO

The history of brick production in Ontario is marked by wide swings in consumption, reflecting both changing technology and changing patterns of use. Until the early part of this century, bricks and natural stone were the most commonly used load-bearing materials for construction purposes. Buildings of four or five stories could be safely constructed if wall thicknesses at the base were 40 to 60 cm. However, as land in the urban centres increased in value, taller buildings provided the opportunity for increased revenue. But thicker walls were not only costly, they also reduced the area of usable floor space. Consequently, structural steel and reinforced concrete framing were developed to act as the structural skeleton on which thin walls could be applied. The brick industry developed its own load-bearing "TTW" units to accomplish the same thing.

Thick walls provided a necessary market for back-up bricks of lesser quality which were unavoidably produced in large numbers by the uneven firing characteristics of the early kilns. Indeed, soft underfired bricks and deformed overfired ones sometimes greatly exceeded the number of bricks which were suitably vitrified and sufficiently durable for exterior use. Fortunately, improved kiln technology closely coincided with the advent of concrete blocks, so that even in residential construction the need was primarily for a durable and attractive brick veneer.

Brickmaking has been a feature of Ontario history from the time of earliest settlement. Local family enterprises using hand-moulding techniques with whatever surface clays were available nearby, and crude wood-fired kilns, were the forerunners of today's modern plants. But advanced brickmaking technology, demand for higher quality, and improved efficiency of larger plants are reflected in a persistent decline in the number of brick producers through industry rationalization. Only in recent years have the numbers of bricks produced reached the levels recorded in the early 1900s (Figure 4.1). In 1985 the production from eight plants finally exceeded that of 1910 when more than 180 plants were active.

The Ontario experience is typical of a worldwide trend: improved technology, efficiency, plant size and road networks have vastly reduced the

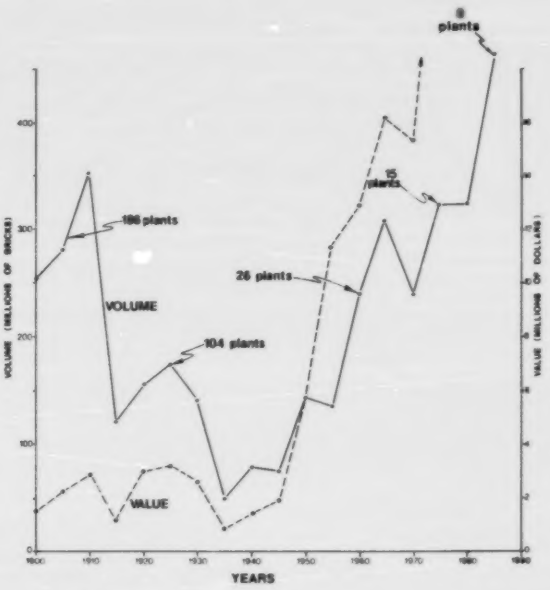

Figure 4.1 Brick production in Ontario, 1900 – 1985.

numbers of producers needed to supply the demand for high quality facing bricks. In the U.K. in 1939 there were 1316 brickworks; in 1982 there were only 35.[18]

BRICK STYLES AND SPECIFICATIONS

Clay bricks are produced in a wide variety of sizes, textures and colours. On January 1, 1978, the construction industry of Canada adopted the metric system of measurement, and Table 4.1 outlines the metric dimensions of the common brick sizes made in Ontario and gives the numbers of bricks needed in each case to cover a wall area of 100 m².

Although they are still referred to as clay bricks, brick manufacturing in Ontario is entirely from shale. Paleozoic shales of the Queenston and Georgian Bay Formations burn naturally to various shades of red through buff, but these colours can be modified by additives, surface coatings and firing techniques to produce varieties of brown, cream and charcoal. Additionally, texturing of the brick face before firing can impose a wide range of rough finishes such as antique, bark, brushed and matte.

Specifications for clay bricks define tolerances for compressive strength, water absorption and dimensional variations. The applicable standards es-

TABLE 4.1 CLAY BRICK SIZES IN COMMON USE IN ONTARIO IN 1985. (6)

Brick Type	Metric Size (Actual mm) W	H	L	Number of Brick per 10 m² (10 mm joints)
100 mm Standard Modular	90	57	190	746
150 mm T.T.W.	140	57	290	498
200 mm T.T.W.	190	57	290	498
100 mm Jumbo (Saxon)	90	90	290	333
150 mm Jumbo	140	90	290	333
200 mm Jumbo	190	90	290	333
Ontario	101.60	60.33	212.73	638
Quebec	95.25	57.15	203.20	699
CSR*	90	71	225	
Paver	90	47	190	

*Now the standard in Ontario

TABLE 4.2 PHYSICAL SPECIFICATIONS FOR CLAY BRICKS, CANADIAN STANDARDS ASSOCIATION. (6)

Imperial	Metric	Title
CSA A82.1	CSA A82.1M	Burned Clay Brick
CSA A82.2	CSA A82.2M	Methods of Sampling and Testing Brick
CSA A82.4	CSA A82.4M	Specification for Structural Clay Load Bearing Wall Tile
CSA A82.5	CSA A82.5M	Structural Clay Non-load Bearing Tile
CSA A82.6	CSA A82.6M	Standard Method for Sampling and Testing Structural Clay Tile
CSA A82.8	CSA A82.8M	Hollow Clay Brick
CSA A179	CSA A179M	Mortar and Grout for Unit Masonry
CSA S304	CSA S304M	Masonry Design and Construction for Buildings. (NBC 1977 Code for Masonry Design.)

TABLE 4.3 PHYSICAL REQUIREMENTS FOR STANDARD CLAY BRICK. (3)

Designation	Minimum Compressive Strength (Brick Flatwise) Gross Area IMPERIAL Average of Five Brick psi	Individual psi	METRIC Average of Five Brick MPa	Individual MPa	Maximum Water Absorption by 5-hour Boiling percent Average of Five Brick	Individual	Maximum Saturation Coefficient* Average of Five Brick	Individual
Type I Brick (exposed)	2,500	2,250	18	16	22.0	25.0	0.88	0.90
Type II Brick (not exposed)	1,500	1,350	11	10	No limit	No limit	No limit	No limit

*The saturation coefficient, or C/B Ratio, is the ratio of absorption by 24-hour submersion in cold water to that after 5-hour submersion in boiling water.

TABLE 4.4 PHYSICAL REQUIREMENTS FOR HOLLOW CLAY BRICK. (4)

Designation	Minimum Compressive Strength (Brick Flatwise) Gross Area IMPERIAL Average of Five Brick psi	Individual psi	METRIC Average of Five Brick MPa	Individual MPa	Maximum Water Absorption by 5-hour Boiling percent Average of Five Brick	Individual	Maximum Saturation Coefficient* Average of Five Brick	Individual
Type I Brick (Exposed)	1,800	1,500	12.5	10.5	22.0	25.0	0.88	0.90
Type II Brick (not exposed)	1,500	1,250	10.5	9	No limit	No limit	No limit	No limit

*The saturation coefficient, or C/B Ratio, is the ratio of absorption by 24-hour submersion in cold water to that after 5-hour submersion in boiling water.

TABLE 4.5 BRICK CLASSIFICATION BY COMPRESSIVE STRENGTH. (3)

Designation	Compressive Strength Average of 5 brick IMPERIAL psi	METRIC MPa	Individual Minimums IMPERIAL psi	METRIC MPa
Type II (not exposed) Type I (exposed)	1,500 and over	11 and over	1,350	10
A	2,500 to 4,500	18 to 30	2,250	16
B	4,501 to 6,000	30 to 42	4,050	27
C	6,001 to 8,000	42 to 55	5,400	38
D	8,001 to 10,000	55 to 70	7,200	50
E	10,001 and over	Over 70	9,000	63

TABLE 4.6 DEVIATION TOLERANCES IN STANDARD CLAY BRICK DIMENSIONS. (3)

IMPERIAL Specified Dimension Inches	Maximum Permissible Deviations from Specified Dimension ±inch	Designation S ±inch	METRIC Specified Dimension mm	Maximum Permissible Deviations from Specified Dimension ±mm	Designation S ±mm
Up to 3 incl.	3/32	1/16	Up to 60 incl.	2	2
Over 3 to 4 incl.	1/8	3/32	Over 60 to 100 incl.	3	2
Over 4 to 6 incl.	3/16	1/8	Over 100 to 150 incl.	5	3
Over 6 to 9 incl.	1/4	5/32	Over 150 to 250 incl.	6	4
Over 9	5/16	7/32	Over 250	8	5

TABLE 4.7 DEVIATION TOLERANCES IN HOLLOW CLAY BRICK DIMENSIONS. (4)

IMPERIAL Specified Nominal Dimension Inches	Maximum Permissible Deviations from Specified Dimension ±inch	METRIC Specified Nominal Dimension mm	Maximum Permissible Deviations from Specified Dimension ±mm
Up to 3 inclusive	3/32	Up to 75 inclusive	2
3 to 4 incl.	2/16	75 to 100 incl.	3
4 to 6 incl.	3/16	100 to 150 incl.	5
6 to 8 incl.	4/16	150 to 200 incl.	6
8 to 12 incl.	5/16	200 to 300 incl.	8
12 to 16 incl.	6/16	300 to 400 incl.	10

tablished by the Canadian Standards Association are listed in Table 4.2. A summary of the physical requirements as to strength and absorption in both imperial and metric terms is given in Tables 4.3 and 4.4 for standard bricks and hollow bricks, respectively. Classification of bricks is further defined by compressive strength for special load–bearing applications as outlined in Table 4.5. Dimensional tolerances for standard bricks and hollow bricks are given in Tables 4.6 and 4.7, respectively.

BRICK TECHNOLOGY

Bricks can be shaped by a number of methods, and in Ontario they have been made by hand–moulding or cutting directly from a clay bank, by soft mud forming in lightly–sanded wood moulds, by dry pressing (Photo 4.1) and by stiff mud extrusion. Plastic surface clays or finely–ground shales can be used in any of these forming methods. In 1964, soft mud moulding, dry pressing and extrusion were in use,[9] but in 1985 all Ontario production was by extrusion of finely–ground and moistened shale.

Brick technology is divided into four main categories, depending on the process stage.

1. Extraction and preparation of the raw material
2. Shaping or forming
3. Drying and firing
4. Inspection and packaging

Extraction and Preparation

Shale extraction is now more often by ripping than by drilling and blasting. The raw material can then be delivered directly to a crushing and grinding circuit or left to 'weather' for a period of time prior to the comminution operation. (The 'weathering' operation takes advantage of weather variations, e.g. sun, rain and frost to break up hard shale and improve its plasticity and workability. Weathering may also be effective in removing soluble salts by dissolution in rain water.) In general, in Ontario only red Queenston shales are intentionally subjected to any degree of weathering. The Georgian Bay grey shales are usually reduced to an extremely fine condition if left to the elements, and develop into unsuitable highly plastic masses which are difficult to handle and process.

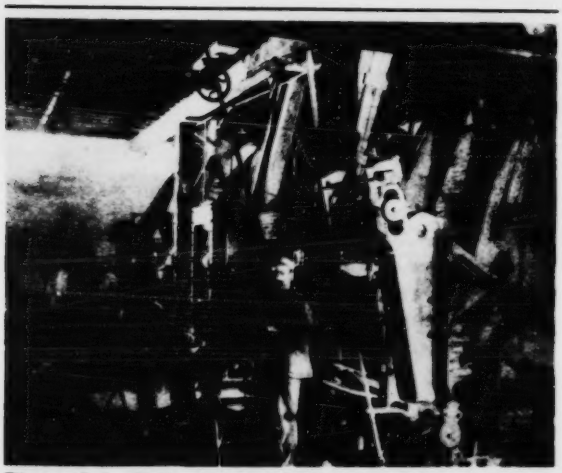

Photo 4.1 Early brickmaking by the dry pressed method. Photo courtesy Clay Brick Association of Canada.

The crushing and grinding operation usually consists of a primary crusher such as Hazemag impact crusher, followed by pan mill grinding (usually with side grate discharge but sometimes bottom grate discharge). The grate size is determined by the grinding characteristics and the extrusion qualities of the ground shale. The discharge from the pan mill is subsequently delivered to a series of screen decks for controlled particle size classification. All oversize material is returned to the pan mill. In general, screen sizes in the range of 8 to 20 mesh are used to grade the feed material to the extrusion lines.

Shaping and Forming

In Ontario, most bricks are formed by the extrusion process (Figure 4.2). Shale raw material is blended with appropriate amounts of barium carbonate to control soluble salts, or colouring pigment (e.g. limestone for buff colours, manganese dioxide for brown colours). Blending and conditioning with water is achieved in either a single or a number of pug mills. The conditioned clay is subsequently delivered to an extrusion machine (current trends are to high power extrusion machines such as the J.C. Steele 90) where the brick is formed. Basically, the extrusion process consists of pushing a column of moist clay through a die using an auger. Surface texturing and surface colouring with sand or slurries takes place immediately after the clay/shale column leaves the extrusion machine. The column is then cut into brick sized slices and automatically loaded onto kiln cars for drying and firing.

Heating of dies makes extrusion much easier as it facilitates the movement of the material column through the die. A means of introducing lubricant is also designed into the die; water, steam or various oils are used as lubricants.

Drying and Firing

Drying of bricks is essentially conducted in warm holding rooms and subsequently in tunnel dryers in

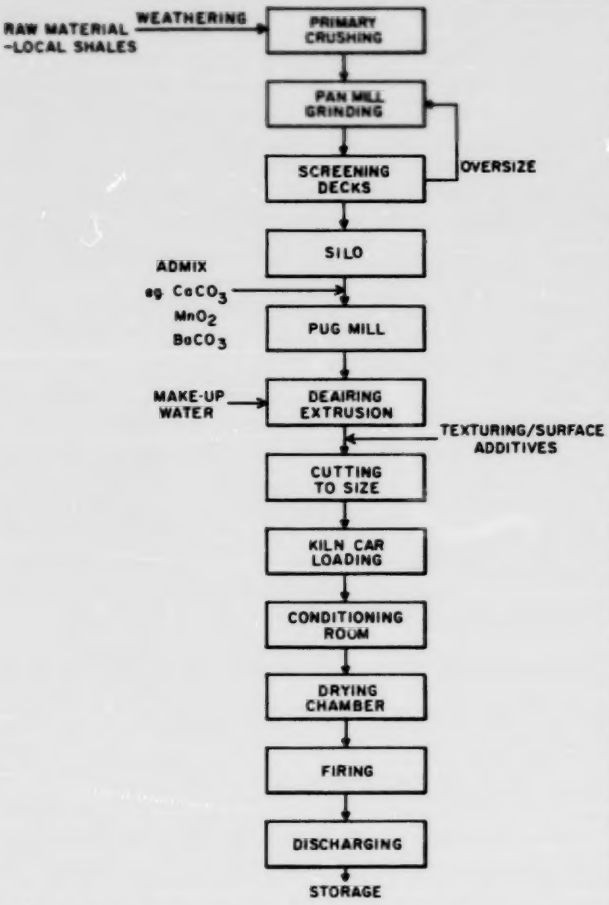

Figure 4.2 Process flow chart for stiff plastic extrusion of brick.

which the ware is heated to approximately 200°C and moisture in the product is reduced from approximately 13% to less than 1%. Heat for the dryers is provided by waste heat from the cooling zone of the tunnel kiln firing operation. This heat may be augmented by auxiliary heat from separate gas burners. Drying is effected not only by application of the heat, but by rapid air movement through the dryer tunnel.

The firing operation is achieved in tunnel kilns which provide high production rates and high thermal efficiency. The tunnel kiln is made up of a series of zones which are carefully controlled in terms of temperature and air movement. Essentially the kiln cars full of bricks move through the tunnel kiln counter to the direction of airflow. The zones through which the bricks pass are identified as the preheat zone, the firing zone, the rapid cool zone, and the cooling zone.

The rate of temperature increase is carefully controlled through the preheat zone to avoid cracks caused by carbon burnout, incomplete drying (presence of moisture) and a quartz inversion (phase change). The firing zone is essentially the soaking temperature at which the brick products are held to assure that the ceramic reactions are completed and the final properties of the product are achieved. For some products, a "flashing zone" is used at the end of the firing zone in which raw fuel is pumped into the furnace and air is excluded. This produces local reducing conditions which cause the iron compounds in the clays and shales to change colour. A variety of buff, browns, reds and blacks can be produced by this technique.

After passing through the firing zones, the products are rapidly cooled from approximately 1040°C to 650°C by injection of cool air into the tunnel by means of rapid cool fans. This process sets the ceramic reactions and the colour. Final cooling from approximately 650°C to 120°C is carefully controlled to avoid cracking due to the quartz inversion.

Inspection and Packaging

Most modern brick plants use automated packaging systems which limit the degree of inspection possible. Today manufacturers are confident of the high degree of quality generated by their manufacturing process. Samples of brick are regularly taken from various parts of a kiln car for quality control testing to ensure specifications are met. Visual examination is conducted on the feed line to the packaging units for colour variations and cracks, and inferior products are removed.

PRICES, COSTS AND GENERAL ECONOMICS

Brick Prices

Prices quoted per thousand bricks in 1986 were in the range $250–300 for Metric Modular and Ontario sizes; prices were 10 percent higher for antique varieties. CSR bricks, now the most common in general use, were quoted at $300–$340. Back up bricks were priced at about $175, sewer bricks $325 and pavers $450–480. All prices include federal sales tax and delivery within the core zone between Oshawa and Stoney Creek.

Fuel Costs

Fuel is a major element in the cost of brick production. Since completion of the Trans Canada Pipeline to Toronto in 1957, natural gas has been used ex-

clusively, replacing oil which was more expensive. Prior to World War II coal was generally used to fire the periodic kilns then in use.

Prior to 1973, fuel costs were $4 to $5 per thousand bricks produced; in 1985 they were $25 to $50. Estimates of fuel costs by the Ontario producers in 1985 ranged from 25 to 35 percent of total production costs. However, new tunnel kilns are more efficient, and new plants planned by Canada Brick and Brampton Brick anticipate fuel costs will decline 25 to 30 percent.

Plant Costs

A new brick plant can expect to have a useful life up to 50 years, assuming normal maintenance and occasional modernization. At the time of writing, both Brampton Brick and Canada Brick were planning new plant construction in the Toronto area.

In 1978 the cost of a new single tunnel kiln plant rated at 35 million bricks annually was estimated at $8 million. It could be doubled to 70 million bricks capacity for an additional $2 million, exclusive of land costs.[16] In 1985 Canada Brick estimated the costs of two new plants it proposes for the Toronto area, with annual capacities of 150 million bricks, at approximately $30 million.

Brampton Brick anticipates a cost of $18 million for a new plant in the Toronto area. Production is rated at 110 million bricks annually. A single tunnel kiln of European design, or two smaller ones, highly fuel efficient and environmentally "clean", are being proposed.

General Economics

To be economically viable, a new brick plant in Ontario should be located within 80 km of Metropolitan Toronto. If a choice must be made, it is preferable to have shale from a remote location transported to a plant near the market centre.

In 1978 the cost of 80 ha of suitable shale land was estimated at $2 million to $3 million ($25,000 to $37,000 per ha). Of this, about 24 ha would be needed for the plant, and for access roads and setbacks; the remainder providing sufficient shale for at least 25 years.[16]

While bricks from the Toronto area are shipped throughout the province and into Quebec, most are consumed within an 80 km radius of the plant. Trucking costs within this area average 10 to 15 percent of delivered prices.[16]

PRODUCTION AND CONSUMPTION

Bricks

In 1985, the market for bricks in Ontario was very strong, continuing the record sales levels of 1984 when more than 400 million clay bricks were sold (Table 4.8). Inventories were very low, as producers were able to sell all the bricks they could produce. Concrete bricks also achieved record sales levels, partly as a result of the insufficient supply of clay bricks.

But in 1982, producers had large unsold inventories of bricks when sales were only about 60 percent of present levels. Indeed, the cyclic nature of brick demand is a major problem for the industry. In the decade 1965 – 1975 the growth in clay brick shipments from Ontario plants averaged about 1 percent per year,[16] and because of current strong demand, growth in the subsequent decade was about the same. But the intervening years 1976 – 1981 were years of no growth, culminating in the steep decline of 1982. Table 4.9 subdivides Ontario brick production by county or regional municipality for the years 1975 – 1984.

Cyclic demand for bricks is a feature of the general economy, reflecting interest rates and the affluence of Ontario's population; up to 90 percent of clay bricks produced are used in residential construction. While brick shipments were lagging behind such traditional indicators as number of housing starts, population increases, and gross provincial product[16] through the 1960s and 1970s, the increasing demand for larger houses has offset that trend in the 1980s.

While clay bricks have traditionally dominated the residential housing market in Ontario, Quebec and British Columbia, other cladding materials are particularly significant in the Atlantic provinces, the Prairies, and the northern areas generally. Table 4.10 gives a regional summary of the use of clay brick in residential housing versus its use in architectural and other markets.

Table 4.11 is a regional breakdown of clay brick sales in Canada for recent years. Ontario accounts for two–thirds of total Canadian brick production.

Shale

Because of the generally inferior properties of surface clays in Ontario, shale is almost exclusively used for brickmaking today.

Allowing for wastage in the quarry and plant, it has been estimated that 3.4 tonnes of shale are consumed in the making of 1,000 bricks.[16] Hence,

TABLE 4.8 THE RECENT RECORD OF ANNUAL BRICK PRODUCTION IN ONTARIO.

	Millions of Bricks Produced*	Value of Bricks $1,000s	Total Clay Products $1,000s
1985	464		
1984	423		
1983	401		
1982	255		
1981	384		
1980	321		
1979	367		
1978	365		
1977	361		
1976	369		
1975	348		
1974	324	25,752	37,969
1973	355	23,679	34,601
1972	359	21,115	31,570
1971	339	18,577	19,815
1970	282	15,275	25,197
1969	369	19,891	31,673
1968	364	18,493	30,629
1967	375	17,261	27,451
1966	323	15,593	25,800
1965	319	16,394	25,131
1964	313	15,575	23,724
1959	272	15,071	22,175
1954	225	11,677	17,230
1949	123	4,660	7,435
1944	57	1,342	2,347

Sources of Information:
1944–74: Ontario Ministry of Natural Resources
1975–85: Clay Brick Association of Canada
*Consumption shown in terms of brick equivalents for 1975–1985

TABLE 4.9 ONTARIO BRICK PRODUCTION 1975–1984. (19)
(Number of bricks sold, by counties or regional municipalities)

	Halton	Hamilton-Wentworth	Niagara	Ottawa-Carlton	Peel	York	Total
1975	72,927,077	7,566,766	9,704,000	31,406,000	181,569,766	39,575,000	415,676,000
1976	79,791,185	7,984,456	10,104,000	34,648,000	196,286,708	39,000,000est.	367,815,000
1977	82,317,559	8,589,677	10,000,000	33,706,000	195,539,830	39,120,800	369,275,000
1978	77,365,300	7,042,428	10,000,000	31,746,706	200,183,295	42,542,000	368,880,000
1979	72,798,000	9,775,652	4,744,526	35,395,417	204,540,000	39,285,000	366,539,000
1980	63,223,687	7,277,120		28,108,000	180,532,104	34,807,000	313,948,000
1981	73,252,000	6,993,069		36,607,063	210,867,000	36,871,000	364,590,000
1982	53,344,000	5,219,600		28,396,303	143,136,000	32,212,000	262,308,000
1983	77,257,000	6,974,834		40,138,614	227,672,000	41,272,000	393,315,000
1984	75,801,000	6,721,377		30,326,762	255,927,000	31,658,267	400,434,000

TABLE 4.10 RESIDENTIAL USE AS A PERCENTAGE OF TOTAL CLAY BRICK SALES. (19)

	Pacific	Prairies	Ontario	Quebec	Atlantic
1982	81.2	59.5	85.8	91.8	51.6
1983	88.5	53.0	92.6	95.5	50.5
1984	89.9	48.4	91.0	96.2	53.5

TABLE 4.11 CANADIAN CLAY BRICK SALES BY REGION.(19)
(thousands of bricks)

	Pacific	Prairies	Ontario	Quebec	Atlantic	Total
1982	14,378	57,375	254,631	110,346	17,651	454,381
1983	20,180	52,174	401,124	158,762	23,209	655,449
1984	15,379	38,626	422,692	135,684	22,590	634,971

TABLE 4.12 POTENTIALLY AVAILABLE RESERVES OF SUITABLE SHALE IN ONTARIO.(16)

County/Region	Geographic Township	Net Reserves Millions of Tonnes	Hectares
Dufferin	Mono	22	134
	Mulmur	125	765
Halton	Esquesing	161	981
	E. Flamborough	113	38
	Nelson	142	870
	Trafalgar	260	1,568
Niagara	Clinton	128	783
	North Grimsby	71	431
	Niagara	4	28
Peel	Albion	30	182
	Caledon	14	83
	Chinguacousy	567	3,468
	Toronto	26	162
	Toronto Gore	179	1,093
Russell	Russell	166	1,012
Simcoe	Nottawasaga	260	1,590
Hamilton-Wentworth	Saltfleet	122	749
Total		2,390	14,605

about 1.5 million tonnes of shale are consumed annually in Ontario at current levels of production. At a bulk density (in situ) of 2.24 tonnes/m^3, 670,000 m^3 of shale are consumed annually. Assuming a working depth of 7.6 m (25 feet), approximately 9 hectares of shale land are needed for current annual brick production in Ontario.

A township–by–township evaluation of possible shale reserves beneath less than 7.6 m (25 feet) of overburden, and unrestricted by development or restrictive zoning, was made in 1978.[18] Table 4.12 is a summary of these reserves, totalling 2390 million tonnes or 14,605 hectares.

Clearly, there is no scarcity of shale lands in the province, although they are not evenly distributed geographically. In fact they are practically restricted to the Toronto–Hamilton area and the lower terraces of the Niagara Escarpment. And while this is advantageous because it coincides with the principal market area, it suffers from greater uncertainty as to availability because of spreading urbanization and socio–environmental pressures. Also, most of these lands have not been tested by drilling and laboratory evaluation; it is almost certain that large areas will prove unsuitable for brickmaking because of unfavourable shale quality. Possible resources of suitable lands will also be limited by the restrictive land use zoning in the Niagara Escarpment Plan.

MARKETING

More than 90 percent of the clay bricks sold in Ontario are used in residential construction where their load–bearing function is minimal and their appeal is largely aesthetic. Clay bricks are unquestionably the preferred exterior finish for housing in the urban areas of southern Ontario. In northern Ontario and other parts of Canada they are less frequently used (Table 4.10) because they are less readily available and more expensive than other local cladding materials.

Architectural, industrial and institutional construction consumes less than 10 percent of the clay bricks sold in Ontario.

Unfortunately, the market for new homes is sensitive to many factors, of which interest rates on mortgage loans, and population trends are only the

more obvious. As a result, brick sales are equally unpredictable over the medium and long term.

In the U.S.A., between 1–1/2 million and 2 million new homes are constructed annually. But an accelerating trend towards renovation of older homes, partly stimulated by widespread urban renewal programs, had slowed that growth in recent years by nearly 20 percent. In the U.K., renovations are averaging about 28 percent of new housing units.[18] The availability of antique and old style bricks for repairing and enlarging early Ontario homes is recognized as a significant market by Ontario producers. Canada Brick, through its McFarren plant, and Hamilton Brick, can more easily respond to special orders by virtue of their batch–style periodic kilns. Brampton Brick will continue production of Toronto Brick's former "John Price" line, and can provide pressed bricks on demand.

Modular housing — prefabricated housing units which can be assembled on site in various numbers and configurations — are expected to become more significant in the U.S.A. because of their lower cost and ability to "grow with the family". This is an obvious market for prefabricated brick panels, an application that has received much research but little development in Ontario.

Other obvious needs in Ontario include large load–bearing bricks, not now produced, and a cream–firing stoneware brick currently produced only on the Prairies. The latter would require import of suitable clay, or development of the Moose River kaolin clays in northeastern Ontario.

One area of strength for clay bricks is the strong demand for luxury housing which favours traditional and natural building materials, such as wood, stone, clay bricks, floor tiles and roofing tiles, almost regardless of cost.

COMPETITIVE MATERIALS

While the general consumption of clay bricks is increasing modestly, the use of alternative materials is also increasing.

Wood, stone, aluminum and plastic sidings are alternative cladding materials of distinctive style, which for reasons of personal aesthetics, geographic location or local availability may be used in place of bricks. But more serious competition is the concrete brick which attempts to duplicate the appearance of clay brick at a lower price.

Concrete bricks (sometimes referred to as "calcite bricks" to distinguish them from concrete foundation blocks and an earlier inferior cement brick) have been constantly improving in quality and appearance over the last decade, and today are enjoying strong demand. Their durability and range of colours has made it difficult for many home buyers to distinguish between clay and concrete bricks.

Concrete bricks are 20 to 30 percent less expensive than clay bricks. In 1985 they were selling in the range of $190 to $220 per thousand, depending on colour and texture, compared with $230 to more than $300 for clay bricks.

In 1980, concrete bricks had about 19 percent of the brick market in Ontario. This had increased to 20 percent by 1982 and an estimated 25 percent in 1984.

The major producers of concrete bricks in Ontario are Canada Building Materials, Primeau Argo Block, Richvale Building Materials, and Brantford Brick.

ECONOMIC AND ENVIRONMENTAL IMPACT

Brickyards in Ontario 150 years ago took their place alongside mills, blacksmith's shops and farms as local family enterprises. Bricks were formed by hand from local plastic clays and fired by wood in crude kilns. They were the building blocks for many second generation homes (after logs) and the rural towns of southern Ontario are still distinctive by the colour and style of these early bricks. Brickyards were small but numerous, and environmental disturbance was largely restricted to the palls of brown smoke from the wood–burning firing process.

In time, these early industries became fewer but larger. Coal replaced wood in the firing process, and subsequently oil and natural gas were the preferred fuels. Environmental disturbance reached its peak in the black smoke of the coal fires.

With the arrival of natural gas in Southern Ontario in 1957, on completion of the Trans Canada Pipeline, stack emissions from brick kilns were reduced to minimal levels.

Today the few remaining brickyards are modern, highly automated industries that cause minimal disturbance to the natural environment. Shale excavation uses a minimum of drilling and blasting, and instead, where possible, the shale quarry is characterized by broad gentle inclines or horizontal benches which are worked by toothed–rippers. This facilitates the benefits of natural weathering before the broken shale is eventually loaded into trucks for haulage to the plant which is usually adjoining. Modern quarrying practices also take into account future site rehabilitation required by Ontario's *Pits and Quarries Control Act*.[17]

Finished bricks are delivered by truck in individual loads of 7,000 to 14,000 bricks. But truck traffic is rarely a problem on local roads; a plant producing 75 million bricks annually might generate 50 return trips per day during the peak season, probably less than a 1 percent increase in traffic volume on an average Ontario highway.

In 1985, there were eight clay brick plants operating in Ontario. They shipped a total of 464,213,000 bricks (Clay Brick Association of Canada, personal communication, 1985).

Despite an abundance of shale lands in the prime market area of southern Ontario, access to new shale reserves is a problem for the industry because of competing land uses. The lengthy and costly public review procedure for quarrying rights adds greatly to the uncertain viability of an industry competing with industries for which an adjoining pit or quarry is not essential (i.e. concrete brick).

New brick plants are planned in the Toronto–Hamilton area before 1990. They will be highly efficient in terms of fuel consumption, and highly protective of the environment. Inevitably they will mean the closing of some older less efficient plants which are now heavily pressed by urban growth, but the net change in employment and economic benefit to Ontario should be minimal.

Environmental Considerations

While the clay brick manufacturing industry is not generally perceived as a major source of industrial pollution, in a few instances it has been identified as a minor source of gaseous (and occasionally particulate) fluorides. Fluoride emissions are generated by the action of heat during the kiln firing process, acting on fluoride and fluorosilicate minerals which may be present in trace amounts in the clay and shale raw materials used for brick manufacture. However, it has been shown that fluorides from brick plant emissions are much less than fluorides in normal dietary and water sources, and a number of studies have concluded no adverse impact on human health.

The impact of fluoride emission control procedures upon energy conservation in tunnel kilns used for manufacturing clay brick has been the subject of an ongoing study funded by Energy, Mines and Resources Canada (CANMET).[10,5,15] Preliminary indications suggest that geological, mineralogical and chemical variations, together with processing variables, can significantly affect fluoride emissions from Canadian brickmaking raw materials. It has also been discovered that a new generation of dry and wet gas scrubber systems capable of functioning in conjunction with a tunnel kiln are under development in France and Germany.

Foreign Technology

Some of the most significant developments being adopted by the industry in North America appear to be European in origin. These include the previously mentioned environmental control technology from Germany, 'soft–mud' forming technology from Holland and France, kiln technology from France and Germany, and automation in manufacturing and handling technology from Spain, France, Germany and Italy.

Probably the most important of the major trends in European technology which might find application in North America are the developments in automation and kiln technology. For example, while North American conveying and packaging technologies use powerful hydraulic systems to handle and move large and heavy volumes of product, the European approach is to use electrical motor–drive handling systems, which are more amenable to automation and computer control. As a consequence, much of the European equipment appears less robust and more intricate than its North American counterpart. However, significant gains are made in production economics by minimizing labour requirements. Fully operating heavy clay plants exist in Europe[14,2] which are totally automated and use as few as 2 – 6 employees per shift, although their production levels are generally small by North American standards.

Improved fuel efficiencies have provided the major driving force around the world to optimize kiln operating procedures and design. Beneficial results have been obtained by improvements in kiln insulation by using fibrous "refractory wool" linings, using lighter kiln–car decks, improved stacking of the product load, incorporation of fuel values into the product load (e.g. sawdust, fly ash), and the utilization of alternative fuel systems (such as sawdust and powdered coal). Most North American companies have applied or tried all of the above and incorporated those techniques which proved beneficial to their particular plant. However, the majority of effort in kiln optimization (particularly for existing installations) focussed on optimizing heat losses and better utilization of waste heat[12] for product drying and plant heating, etc. A natural progression of this approach in North America has been the development of larger, wider kilns (firing more product for virtually equivalent heat losses). Major efforts to improve heat circulation throughout the kiln load, together with combinations of all of

the above, have resulted in significant reductions in firing times, and therefore reduced fuel costs.

The advent of fibrous refractory insulation brought about many kiln design changes. At the forefront were the European designed prefabricated modular kilns.[8,4] Such systems provided minimal energy loss and highly flexible designs. The most recent modification of this concept is the French "Hydrocase" kiln concept[14] in which the kiln operates under positive pressure and utilizes an undercar gas/air seal of water. Conventional North American kilns utilize fans to pull air and hot gases through a tunnel kiln and use sand seals to prevent escape of furnace gases or intrusion of cold outside air. In the new French kiln the bottom of the car is submerged in water to provide the necessary seal, and air is forced into the furnace through the cooling zone to the front and exit stack of the furnace. The prototype of this kiln has currently completed a 2–year continuous plant trial with excellent fuel economics of the order of 625 Btu/lb (1.45 MJ/kg). One of the European technologies which has not been adopted to any significant level in Canada is the mechanical soft mud production technology. This technology is ideally suited to small–scale production, since it consists of small modules which can be easily combined to manufacture larger quantities. In principle, the technology uses a modern mechanical approach to an old manufacturing technique; machines are used to throw 'soft mud' lumps of clay into sanded wood mould boxes. The moulds are then automatically converted onto a conveyor and the green bricks are handled by conventional conveying, drying and kiln technology.

The advantages of such a system are:

1. a variety of shapes and sanded coloured products can be manufactured, giving high flexibility;
2. the system is essentially simple in concept, and therefore easy to operate with minimal maintenance costs;
3. the system is suitable for smaller–scale production (but production may require the use of a highly efficient periodic kiln);
4. the products are perceived to be of high quality and high value due to their 'antique' appearance.

Plants using this technology operate with a minimum of staff, and could be adopted by a Canadian producer. However, the production of 'antique' soft mud bricks is aimed at the premium end of the market.

ONTARIO BRICK PLANTS

Eight plants produced clay bricks in Ontario in 1985. The recent (1985) acquisition of Domtar's operations at Mississauga and Ottawa increased Canada Brick's presence in Ontario to five active brick plants. Brampton Brick presently operates both its Brampton and Don Valley plants. Hamilton Brick is the last of the independent family–owned plants which were so numerous in years past.

The eight active plants (Figure 4.3) are described on the following pages. Although now inactive, the former Thunderbrick plant at Thunder Bay is also briefly described.

BRAMPTON BRICK

Brampton Brick is a family–owned firm that has been making bricks for 120 years, for most of that time at its present location just north of Brampton. In 1984, it purchased the recently–closed plant of Toronto Brick in the Don Valley, and it is continuing, temporarily, to operate that plant. However, the company plans to open an all new plant in the next few years, at which time the older plants will be phased out. Urban pressure is the main reason for ultimate closure of the Brampton and Don Valley sites.

Brampton Plant

The Brampton plant and quarry are described in various references.[9,1,11,13] For many years bricks were made exclusively by the dry–press method, and the company name was Brampton Pressed Brick. But in 1963 the Brampton plant was converted to the extrusion process, and currently is rated at a capacity of 60 million bricks annually. The operation employs 110 people year–round.

A 25 m section of red Queenston Shale is exposed in the quarry that adjoins the plant. In recent years a minimum of blasting has been used to loosen the shale. Ripping by bulldozer is generally used instead. The top 15 m of the shale section has been previously described and tested in detail.[9]

Grinding of the shale to 16 mesh is accomplished by drypans in closed circuit with heated vibrating screens. The brick stream is extruded by a J.C. Steele 90 extruder and the bricks are cut by a Steele cutter. Bricks are automatically set on rail cars for drying and firing. Drying is accomplished in 48 hours in waste heat tunnels.

In 1970 a gas–fired tunnel kiln replaced the five periodic kilns, and a second tunnel kiln was added in 1977. Firing time is about 24 hours.

Bricks are made in four sizes: Ontario, Modular, Tempo and M–Cat. They are packaged in cubes of 500 for truck delivery.

Don Valley Plant

The Don Valley plant, built in 1889, was known successively as The Don Valley Pressed Brick Company, The Don Valley Brick Works, and Toronto Brick Company. In 1956 it was acquired by German interests and was operated as a division of United Ceramics Limited until 1984. The site is now slated for redevelopment, but Brampton Brick has purchased the plant and equipment, and is allowed to operate temporarily before salvaging it.

In recent years bricks have been made almost exclusively from Georgian Bay Shale obtained from an adjoining quarry behind the plant. Shale was quarried to a depth of about 30 m. Above the shale is a 26 m section of glacial varved clays and interglacial sandy clays that have also been used in the past for brickmaking. This section of unconsolidated clays and sands is internationally famous for its excellent scientific record of several glacial events and an intervening warm interglacial stage.[8]

The Don Valley plant is capable of great diversity in brickmaking. While most of the production today is extruded from a J. C. Steele 90 machine, antique "John Price" bricks are also made, and dry press bricks are made on order. Drying is accomplished in waste–heat tunnels. Two Harrop gas–fired tunnel kilns are used for most of the production, but a third smaller tunnel kiln is used for John Price bricks. The application of a ceramic glaze to the exposed brick face has been discontinued, as has the production of sand–lime bricks. Ontario, Modular and John Price bricks are produced.

Proposed Plant

While there have been numerous delays due to local environmental concerns, Brampton Brick expects to proceed with a new plant soon. The proposed new plant will have an annual capacity of 110 million bricks, and will cost about $18 million to construct. It is expected that a J. C. Steele 90 extrusion machine will handle most of the production, but the

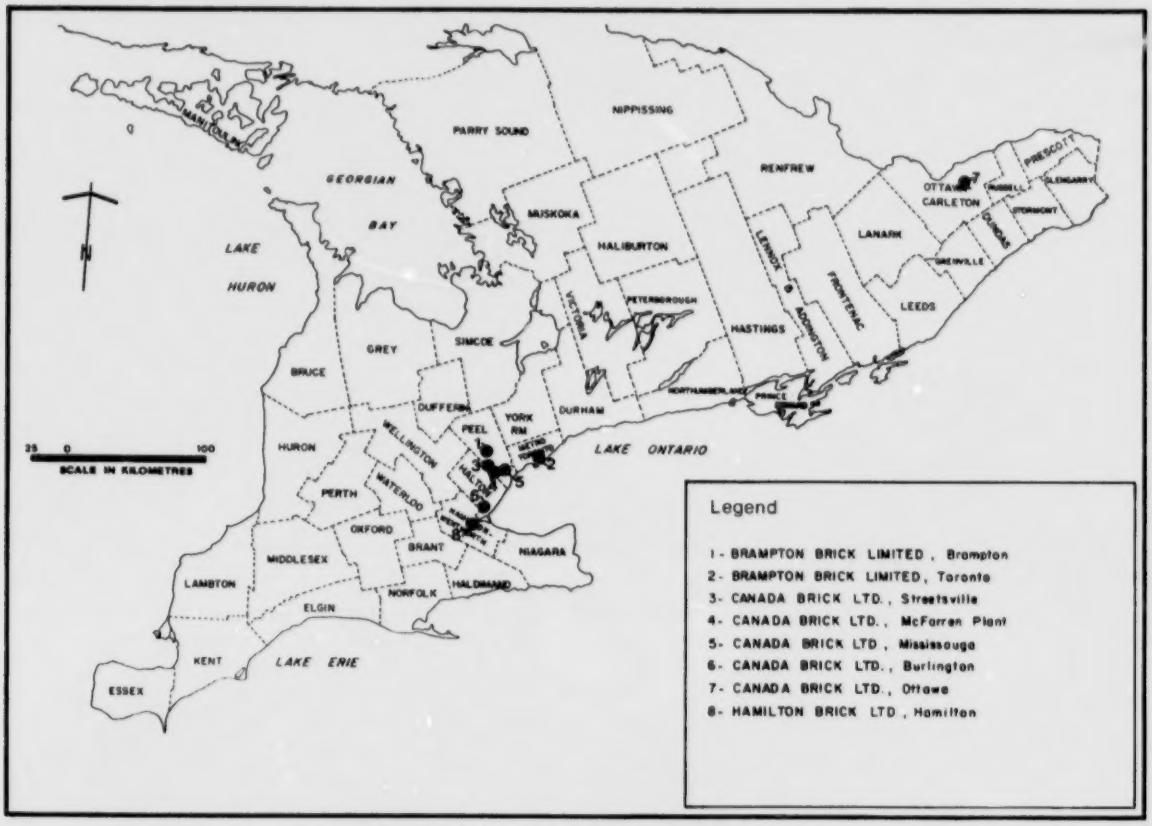

Figure 4.3 Brick plants in Ontario.

John Price processing equipment will be relocated from the Don Valley plant.

A single large tunnel kiln, or two smaller ones, of European design are planned. The kiln(s) are expected to be considerably more fuel efficient than those operating at Brampton and Don Valley, and will have highly effective stack scrubbers for removal of fluorides and particulate matter.

A work force of 150 to 200 is anticipated. The production of other clay products such as roofing tiles is being considered.

CANADA BRICK

Canada Brick is a wholly–owned subsidiary of Jannock Limited, a Canadian company involved also in the production of various steel products and electrical components. Canada Brick dominates the clay brick industry in Ontario and Quebec. With its recent (1985) purchase of Domtar's brickmaking facilities, it now operates five plants in Ontario and two at LaPrairie, Quebec.

In 1976, Jannock also entered the U.S.A. brick market with the purchase of a plant at Corunna, Michigan. Subsequent acquisitions include the Sipple Brick plant in Stanton, Kentucky, Tiffany Brick and a former pipe plant in Texas. Currently, Canada Brick operates three clay plants and one concrete plant in Texas under the name of U.S. Brick.

Canada Brick's five Ontario plants are described in the following notes. In 1985, the company announced its intention to build two new plants in the area west of Toronto.

Canada Brick, Burlington

The Burlington Plant of Canada Brick (formerly Diamond Clay Products Limited) commenced brick production in 1958, using Queenston Shale from the valley of nearby Bronte Creek. The plant and pit are located in lots 3 and 4, concession I, N.D.S., in Burlington, Halton Region. A description of the previous operation is given by Guillet.[9]

The majority of bricks are produced in CSR size, but other sizes such as Ontario and Modular are also made. Capacity of the plant is approximately 75 million.

The shale in the quarry is ripped by a bulldozer and pushed into a stockpile. Shales from other pits are trucked in and also stockpiled. A front–end loader mixes the shales to give the required colours and plasticity. The same loader then brings the mixed shales to a hopper at the plant crusher building. The shale is delivered by apron feeder to a single roll crusher, and then to a rim discharge dry pan. The ground shale is next conveyed to a bank of heated screens varying from 8 to 16 mesh. Oversize from the screens is further ground in an impact crusher and returned to the screens. Undersize shale from the screens is conveyed to a feed hopper and the first of two pug mills where water is added. The pugged shale is extruded by a vacuum extruder.

Floor bins hold a reserve of ground shale in case of a breakdown in the grinding plant.

The column of clay exiting the extruder is coated and/or textured by any of several means and cut into slugs. The slugs are pushed through a bank of vertical wires spaced at the thickness of individual brick. These cut groups of brick are picked up by a setting machine two rows high, and placed on a tunnel kiln car. The cars of green brick go to a holding area from which they are sent through one of three tunnel drier–kilns.

Drying and firing takes 3 to 4 days, peaking at up to 1070°C.

The fired bricks are mechanically unloaded from the cars, inspected for quality and regrouped into cubes of 500 each.

The cubes are steel strapped and carried by fork–lift trucks into the storage yard, ready for shipment.

Canada Brick, McFarren Plant

The plant is located on the southern limits of Streetsville and was built in 1913. The shale quarry and the plant are in lot 3, Concession V, W.H.S. near Streetsville, Peel Region. Descriptions of earlier operations are given by Keele,[11] Montgomery[13] and Guillet.[9]

Bricks are produced in a complete range of colours, in antique or traditional texture, or as paving brick.

The principal size is Ontario, but CSR, Modular and Jumbo are also produced.

The Queenston Shale is removed by ripping the face with a bulldozer and then pushing it into a stockpile. A front–end loader loads a dump truck which takes the shale to a storage hopper at the grinding plant. The shale is fed to a single roll crusher and then to a dry pan. The ground shale is next conveyed to a set of screens, where the oversize is in a closed circuit with a hammer mill. The undersize is stored in a steel bin from which it is fed to two pug mills and then to a vacuum extruder.

The extruder column is cut into brick by a rotary cutter. They are then placed on drier cars in

300 brick cubes, which are subsequently handled by fork–lift trucks.

The cars of brick are placed in tunnel driers heated recuperatively from the kiln exhaust. The cubes of dried brick are stacked in one of five periodic kilns where they are fired on 7– to 11–day cycles, peaking at 1090°C.

When the kiln is cooled, fork–lift trucks remove the cubes of brick from the kilns. They are placed in a sorting area, inspected, packaged into cubes of 500 bricks and taken to the storage yard ready for shipment.

Canada Brick, Mississauga

Brick production at this former Domtar location commenced in 1911. It was purchased by Canada Brick in mid–1985. History and descriptions of the earlier operations are given by Montgomery[13] and Guillet.[9] Domtar actually operated two brick plants for a few years on the Mississauga site: the original periodic kiln plant which was closed in 1970, and a tunnel kiln plant constructed in 1959 which is still operating. An expanded shale aggregate, Haydite, was also produced during the years 1928–1980.

Other Domtar brick plants in Ontario included a dry–pressed plant at Cheltenham, closed in 1964; and a tunnel kiln plant near Ottawa which has been operating since 1961. Domtar also operated two brick plants in the state of Mississippi and the LaPrairie plant in Quebec.

The Plant

Starting in 1959 with a single tunnel kiln, a second was added in 1966, bringing the existing Mississauga plant to an annual capacity of 70 million bricks. Grey Georgian Bay Shale from the adjacent quarry is crushed and screened to 16 mesh in a sequence of rolls crushers, drypans and heated vibrating screens. Tempering water is added to two pugmills which feed two Steele 90 extrusion machines capable of producing 25,000 bricks per hour. Barium carbonate, limestone and manganese are added as required for colour and scum control. Dino automatic stacking equipment stacks green bricks for drying and firing.

Bricks are dried for about 48 hours in four drying tunnels with capacities of 17 cars each. The tunnels are heated by waste heat from the kiln. The two gas–fired tunnel kilns each hold 38 cars, and produce finished bricks at the rate of 200,000 per day. Total elapsed time in the kilns is 40 hours. One car is discharged every 65 minutes from each kiln. Finished bricks are automatically palletized in 500–brick cubes. CSR, Ontario and Modular brick sizes are made, CSR being in largest demand.

The Quarry

The quarry has been previously described by Guillet.[9] Since then it has been deepened to 27 m, and is worked by drilling and blasting. Chlorides are a problem in the lower levels, so brick shale is taken only from the upper 12 m. The lower shale was formerly used only in the production of Haydite, but in 1985 these levels were being backfilled with flyash from Ontario Hydro's coal–fired Lakeview generating plant.

Canada Brick, Ottawa

Canada Brick's Ottawa plant was built by Domtar Construction Materials Limited in 1961 to replace the operations of Ottawa Brick and Terra Cotta Company Limited which were closed in 1960. Domtar sold its plant to Canada Brick in mid–1985, along with its Mississauga plant. Red Queenston Shale is trucked 26 km to the plant from a quarry near Russell. Early brickmaking in the Ottawa area is mentioned by Baker,[1] Keele,[11] Montgomery[13] and Guillet.[9]

Shale is quarried and trucked to the plant under contract. A stockpile in excess of 60,000 tonnes is accumulated during the summer months to feed the plant through the winter. The shale is improved for brickmaking by natural weathering, both in the stockpile and on the quarry floor. Plant feed is reclaimed from stockpile by front–end loader and is crushed and ground through 16 mesh by impact crusher and drypan in closed circuit with four heated vibrating screens. Ground shale is stored in two silos and conveyed to a primary pugging section before final pugging and extrusion. Bricks are mechanically loaded on cars for drying and firing.

A 5–track holding room has space for 40 cars ahead of the dryers. Drying is accomplished using waste heat augmented by gas in three tunnels which accommodate 14 cars each. A gas–fired tunnel kiln 122 m long has room for 38 cars, and fires to peak temperatures of 1050°C. One car is discharged every 90 minutes, and the bricks are mechanically unloaded and steel–strapped in cubes. CSR and Modular sizes are produced.

The Quarry

The quarry is in lot 18, concession III, Russell Township, in the united counties of Prescott and Russell, taking advantage of a small shallow occur-

rence of red Queenston Shale. It has been previously described.[9]

Canada Brick, Streetsville

The Streetsville plant of Canada Brick commenced operations in March 1956. Both the quarry and plant are located on the northwest limits of Streetsville in lot 6, concession V, W.H.S., Mississauga, Peel Region. A description of earlier operations is given by Guillet.[9]

The plant is the largest in Ontario, producing over 100 million bricks annually. Although CSR is the principal size produced, Ontario, Modular and TTW are also made in a wide range of colours and textures.

Overburden is stripped off the Queenston Shale by scraper–type earth movers. A large bulldozer then rips the face of the exposed shale and pushes it into stockpiles.

A front–end loader loads the shale into a Euclid truck for the 300 m haul to the crushing plant hopper. The shale is fed first to a Dixie and then a Williams hammermill, then conveyed to a set of screens. Undersize from the screens is conveyed to one of five 455 tonne storage silos. The oversize shale is conveyed to two rim discharge grinders in closed circuit with another set of screens, and the undersize is conveyed to the ground shale storage silos.

Feeders under the silos proportion the ground shale to one or both of two extrusion lines. Each line is composed of two pug mills and a vacuum extruder.

The column of clay exiting the extruder is coated and/or textured by any of several means and cut into slugs. The slugs are then pushed through a bank of vertical wires spaced at the thickness of individual brick. These cut groups of brick are picked up, two rows high and placed on a tunnel kiln car by a setting machine. The cars of green brick go to a holding area from which they are forwarded to one of four tunnel drier–kilns (Photo 4.2).

Drying and firing takes 3 to 4 days, peaking at up to 1070°C.

The fired brick are mechanically unloaded from the cars, inspected for quality and regrouped into cubes of 500 each.

The cubes are steel strapped and carried by fork–lift trucks into the storage yard, ready for shipment.

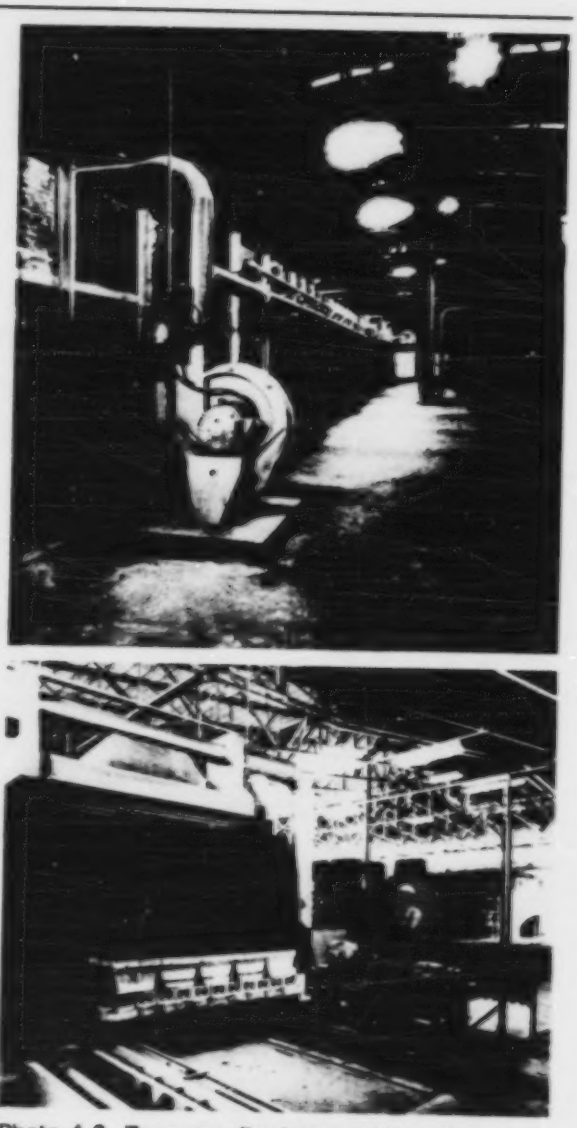

Photo 4.2 Top: gas–fired tunnel kilns. Bottom: loading a car into tunnel kiln. Canada Brick, Streetsville. Photo courtesy Clay Brick Association of Canada.

HAMILTON BRICK LIMITED

The Hamilton Brick plant was built in 1907 to take advantage of a 25 m section of red Queenston Shale exposed in the Escarpment behind the plant. Shale is now trucked from Burlington. Descriptions of earlier operations are given by Montgomery[13] and Guillet.[9]

Queenston Shale from the Burlington quarries of National Sewer Pipe Limited is trucked 15 km and stockpiled behind the plant. Grinding of the

shale to 8 mesh is accomplished in a 3 m Bonnot drypan in closed circuit with two Tyler heated vibrating screens. Minor amounts of barium carbonate, manganese dioxide and Lignosol may be added to the ground shale before its storage in a small bin. The brick stream is extruded by a Connot Greyhound vacuum extruder, and is textured or coated before cutting by a Steele No. 18 cutter. The green bricks are placed in units of 350, two units per car, for subsequent handling by forklift.

An 8–track tunnel dryer is gas–heated and can accommodate 15 cars per track. Drying time is 48 hours at 90°C. Five beehive kilns 12 m in diameter each hold 100,000 bricks. They are gas–fired to peak temperatures of 1040°C on a burning cycle of 96 to 100 hours.

In 1985 a new 9.5 m square Swindel Dressler downdraft kiln was constructed. It is fibre lined with an exterior steel shell, and is gas–fired through 12 burners located in vertical banks of three at the corners. The burner jets are designed to create high velocities of heated air around the inside periphery of the kiln, discharging through a central downdraft port in the floor. The new kiln is expected to realize fuel savings of 30 percent, and will operate on a 7–day turnover cycle. Peak firing temperature will be 1070°C.

Hamilton Brick estimates their costs for fuel and labour are each about one–third of their total costs. The plant operates year round with a workforce of 33, and produces about 9 million bricks annually, primarily in the standard Ontario size. Demand for their bricks was extremely heavy in 1985.

THUNDERBRICK LIMITED

In 1976, Thunderbrick Limited, a subsidiary of Portland Zementwerke–Wossingen GmbH of Frankfurt, Germany, acquired the Rosslyn plant of Superior Brick and Tile Company Limited near Thunder Bay. It was reported to have spent $4.8 million in redesigning and outfitting the plant for brick and split floor tile production.[7] In 1985 the plant was optioned to Great Lakes Ceramics Limited which anticipated production of split floor tile before year end.

The Superior brick plant and its associated clay pit have been described by Guillet.[9] After its acquisition by Thunderbrick, the plant was totally renovated and modernized for a designed production of 20 million bricks annually. A new clay pit was established approximately 5 km south of the plant. Here, 4.5 m of brown clay was found to overlie as much as 17 m of blue clay.[7] Subsequently, a blend of both clay and shale was used. Great Lakes Ceramics plans to use a stoneware clay from Rockglen in southern Saskatchewan in its floor tile production.

The Thunderbrick plant was designed by Lingl of Germany. Clay and shale preparation include three stages of grinding in Hazemag and Raymond mills, followed by drying of the fine products before storage. Batching is accomplished by automatic weight and some level detection devices, and the feed is mixed in a J. C. Steele wet pan mixer with or without an auxiliary pug mill. Both bricks and split tile are made by extrusion, the tile using a Breitonback machine. Green ware is loaded on pallets and transferred automatically to holding and drying rooms. From the dryers, the ware is transferred to kiln cars via a Lingl setting machine, thence to the Lingl top–fired 85 m tunnel kiln.

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Chapter 5 — Drainage Tile

DRAINAGE TILE

The production of clay drainage tile (Photo 5.1) in Ontario is currently following a severe worldwide decline. Plastic drainage tubing is generally less costly to produce and install, although it remains to be proven whether it is as effective and durable in the long term.

It was a fortunate coincidence that the widespread practice of field drainage in the first half of this century (Photo 5.2) provided an opening for an alternative product for numerous small clay brick plants that were competing unfavourably with large new shale plants. Surface clays in Ontario do not, in general, make dense well–vitrified bodies, and their use in brickmaking was increasingly jeopardized by the superior firing qualities of Paleozoic shales. Specifications for drainage tiles allowed a less vitrified, softer and more porous body, irrespective of colour or appearance. Without the expanding drainage tile market, many local brick makers would

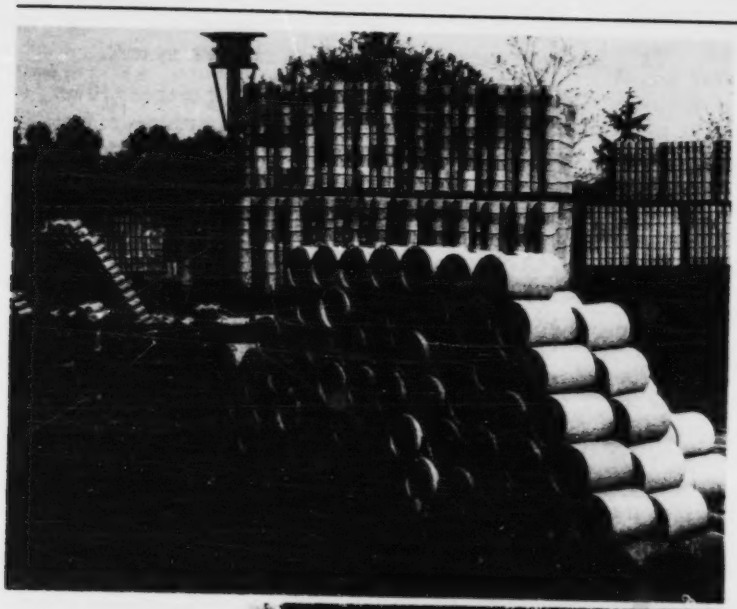

Photo 5.1 Drainage tiles of various sizes. D.A. Janes and Son Limited, Mount Brydges. Photo courtesy B.H. Feenstra.

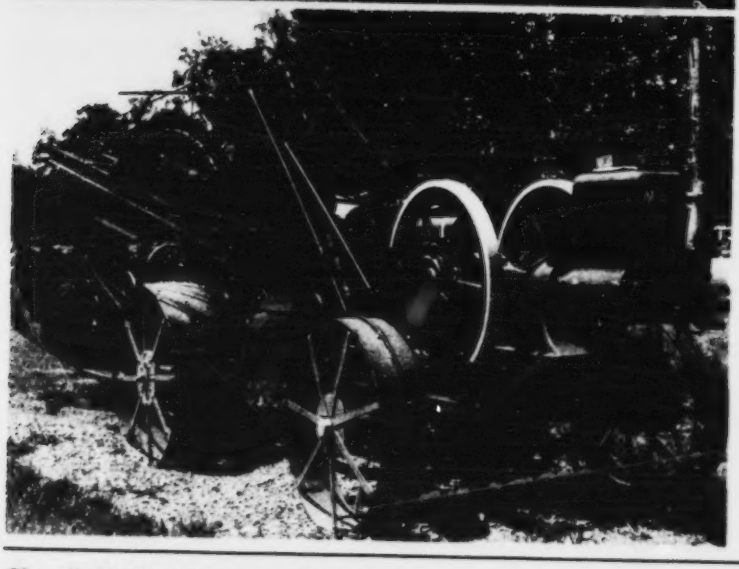

Photo 5.2 "Buckeye", an early clay drainage tile setter. Photo courtesy Amos C. Martin Ltd.

have long since closed. Instead, the number of drainage tile plants showed strong growth until about the middle of this century, and then declined (Table 5.1).

TABLE 5.1 ACTIVE DRAINAGE TILE PLANTS FOR SELECTED YEARS.(3)

1985	5
1964	31
1929	84
1906	51

The first producer of plastic drainage tubing in Ontario commenced production in 1968, the year of peak clay tile production when 68.4 million tiles of 4–inch (10 cm) equivalent size were made. There were also ten producers of concrete tile at that time, but their combined production was only about 6 million tiles.[9] A major decline in the number of clay tile plants took place during a period of expanding production (1929–1964); closures that reflected inability to modernize or compete with more aggressive tile producers. Concrete tile was never a serious threat in the smaller sizes, but plastic tubing has had a significant impact and has reduced the clay tile industry to its present low level of activity.

Field drainage by systems of tile liners allows the farmer perhaps two weeks earlier access to his lands in the spring and increases crop yields in wet seasons. It has been found to be much more effective than open drainage ditches, which was the drainage technique commonly used in earlier times.

AGRICULTURAL DRAINAGE

Drainage tile and tubing finds application in both agricultural and municipal areas. Agricultural field drainage consumes about 85 percent of tile and tubing production. Municipal uses are largely for residential subdivisions to control surface run–off.

Field drainage lengthens the growing season by permitting earlier access to the ground in the spring. It also increases crop yields in wet seasons by removing surplus moisture, and it benefits crops in dry seasons by encouraging deeper root systems. The cost of field drainage is usually recovered within a few years through increased crop yields.

Farm drainage is thoroughly described in a number of publications of the Ontario Ministry of Agriculture and Food, all of which have been written by Professor R. W. Irwin, with assistance in some cases from other staff at the Ontario Agricultural College, University of Guelph.

Publication 4 — *Farm tile drainage assistance*

Publication 29 — *Drainage guide for Ontario*

Publication 36 — *Laying tile by hand*

Publication 501 — *Farm drainage*

Under Ontario's *Tile Drainage Act*, farmers can borrow up to 75 percent of the cost of the drainage work at an interest rate of 4 percent. Additionally, the Ontario Ministry of Agriculture and Food will prepare a drainage survey plan without cost to the farmer. Tiling contractors use continuous bucket wheel excavators in laying clay tile. Plastic tubing is installed by a plough technique which causes minimal disturbance of the soil, and this technique has been recently adapted for clay tile as well.

Drainage lines are normally 4 inches (10 cm) in diameter and spaced according to soil type: from 40 to 50 feet (12–15 m) in clay soils, 50 to 70 feet (15–20 m) in sand or loam soils (Imperial measurements are still in general use in the clay tile industry). Recommended depths are 2 to 2–1/2 feet (60–75 cm) in clay soils, 2–1/2 to 3–1/2 feet (75–100 cm) in sand or loam soils. The lines should slope at least 1 inch per 100 feet (8 cm per 100 m). Collector lines are larger in diameter than the normal 4 inch (10 cm) feeder lines and are connected to them by Y or T joints. Discharge of water may be by gravity into open trenches or pumped away from collecting sumps as necessary.

Early tiling practice was often at more widely spaced intervals than presently recommended. In some cases compaction of the soil by heavy farm equipment has necessitated the further installation of intermediate lines to upgrade the system.

In sandy soils a nylon sleeve around clay tile may be necessary to prevent blockage of the tile's drainage capacity by sand.

SPECIFICATIONS

Clay drainage tiles are subject to the standards established by the American Society for Testing and Materials (ASTM) as set out in Designation C 4 (Clay Drain Tile) and Designation C 498 (Perforated Clay Drain Tile), and summarized in Table 5.2. In 1970, Ontario manufacturers officially adopted these standards except for the absorption factor and the freeze and thaw test in the Standard tile class. Many Ontario surface clays do not readily vitrify to dense bodies of low porosity, yet their performance appears to have been generally satisfactory.

Ontario manufacturers of concrete drain pipe have adopted the standards set out in ASTM Designation C 412, as summarized in Table 5.3.

Both clay and concrete drain pipe should be straight and approximately circular in cross–section. Ends should be square and the inside surfaces smooth. They should be free from cracks, broken pieces, and checks which may decrease strength or admit soil into the drain. Where drain pipe may be crushed by loads applied by machinery or other traffic, or where frost is a problem, sewer pipe or corrugated steel should be used.

Corrugated plastic tubing must be resistant to chemicals present in soils and ground waters, and from degradation due to ultra–violet light. Tolerances have been defined by the Canadian General Standards Board as specification 41–GP–29 Ma

TABLE 5.2 PHYSICAL TEST REQUIREMENTS FOR CLAY DRAIN TILE.

	Standard Drain Tile				Extra–Quality Tile				Heavy–Duty Drain Tile			
	Minimum Crushing Strength* (kN/m)		Max. Water Absorption by 5–Hr. Boiling (%)		Minimum Crushing Strength* (kN/m)		Max. Water Absorption by 5–Hr. Boiling (%)		Minimum Crushing Strength (kN/m)		Max. Water Absorption by 5–Hr. Boiling (%)	
Internal Dia. (mm)	Av. of 5	Ind.	Av. of 5	Ind.	Av. of 5	Ind.	Av. of 5	Ind.	Av. of 5	Ind.	Av. of 5	Ind.
100	11.7	9.9	13	16	16.0	14.4	11	13	20.4	18.4	11	13
125	11.7	9.9	13	16	16.0	14.4	11	13	20.4	18.4	11	13
150	11.7	9.9	13	16	16.0	14.4	11	13	20.4	18.4	11	13
200	11.7	9.9	13	16	16.0	14.4	11	13	21.8	19.7	11	13
250	11.7	9.9	13	16	16.0	14.4	11	13	22.6	20.4	11	13
300	11.7	9.9	13	16	16.0	14.4	11	13	24.8	22.3	11	13
350	12.3	10.5	13	16	16.0	14.4	11	13	27.0	24.2	11	13
375	12.7	10.8	13	16	16.7	15.0	11	13	28.9	26.0	11	13
400					17.5	15.7	11	13	30.6	27.6	11	13

Abbreviations: Dia = Diameter; Av = Average; Ind = Individual

*Strength determined by a three–edge–bearing method

Note: Tiles that exceed the maximum permissible water absorption requirement may be tested by a freezing and thawing method. Tiles shall not lose more than 5 percent of their original dry weight as a result of 36 freezing and thawing cycles in the Standard class, and 48 cycles in the Extra–quality and Heavy–duty classes.

Source: ASTM Designations C 4 and C 498

TABLE 5.3 PHYSICAL TEST REQUIREMENTS FOR CONCRETE DRAIN TILE.

	Standard Drain Tile				Extra–Quality Tile				Special Quality Tile		
	Three Edge Bearing Crushing Strength (kN/lin m) Min.		Absorption Boiled 5 Hr. (%) Max.			Three Edge Bearing Crushing Strength (kN/lin m) Min.		Absorption Boiled 5 Hr. (%) Max.		Three Edge Bearing Crushing Strength (kN/lin m) Min.	Absorption Boiled 5 Hr. (%) Max.	
Nominal Inside Dia. (mm)	Av.	Ind.	Av.	Ind.	Nominal Shell Thickness (mm)	Av.	Ind.	Av.	Ind.	Ind.	Av.	Ind.
100	11.5	10.0	10	11	13	16.0	14.5	9	10	16.0	8	9
125	11.5	10.0	10	11	14	16.0	14.5	9	10	16.0	8	9
150	11.5	10.0	10	11	16	16.0	14.5	9	10	16.0	8	9
200	11.5	10.0	10	11	19	16.0	14.5	9	10	16.0	8	9
250	11.5	10.0	10	11	22	16.0	14.5	9	10	16.0	8	9
300	11.5	10.0	10	11	25	16.0	14.5	9	10	16.0	8	9
350					29	16.0	14.5	9	10	16.0	8	9
375					32	16.0	14.5	9	10	16.0	8	9
400					35	16.0	14.5	9	10	16.0	8	9
450					38	17.5	16.0	9	10	17.5	8	9
500					41	19.5	17.5	9	10	19.5	8	9
550					44	21.5	19.0	9	10	21.5	8	9
600					50	23.5	21.0	9	10	21.5	8	9

Abbreviations: Av = Average; Ind = Individual; Diam = Diameter

Source: ASTM Designation C 412.

(November 1983). Three classes of plastic tubing are considered:

Type 1 – Nonperforated

Type 2 – Perforated

Type 3 – Tubing with special perforations for applications other than agricultural land drainage

The specifications for plastic tubing outline acceptable standards for dimensional tolerances, water openings, stiffness and impact resistance. The testing procedures are the same as those defined by the American Society for Testing and Materials (ASTM):

D 618 – Methods of conditioning plastics and electrical insulating materials

D 2122 – Method of determining dimensions of thermoplastic pipe and fittings

D 2412 – Method of test for external loading properties of plastic pipe by parallel–plate loading.

TECHNOLOGY AND ECONOMICS

It is an unfortunate fact that Ontario's surficial clays are generally poor as raw materials for fired clay products. They tend to be high in lime, and hence burn to a rather soft porous body, sometimes cream or yellow–coloured and almost chalky in texture. However, some red–burning clays do occur, notably in the Ottawa Valley and in extreme southwestern Ontario, and these do vitrify over a short temperature range, giving denser and stronger bodies. Paleozoic shales of the Queenston, Georgian Bay and Arkona Formations are the best raw materials, and nearly all Ontario producers of heavy clay products now use these shales. Figure 5.1 illustrates the process for drainage tile production.

While some Ontario drainage tiles made from clay may not meet absorption specifications, they still have a good service record in the ground. An assessment of the quality of tiles from 30 clay plants, 5 shale plants and 5 concrete tile plants in 1959 revealed that tiles made from shales were superior to both clay and concrete tiles in strength, and equal to concrete tiles, but much superior to clay tiles in absorption.[5] However, the study concluded that, because of the uncertain relationship between laboratory testing and actual field performance, "the absorption factor (in clay tiles) should not cause undue concern".[5]

The drainage tile industry of 1969 included 6 plants using shale, 27 using clay, 10 using concrete and 2 plastic pipe producers. This was the year of maximum recorded clay tile production, and it is interesting to note that expanding tile production was largely accounted for by shale plants as opposed to producers using surface clays; again, clay tile quality was recognized as being low because of the generally inferior quality of Ontario clay. However, a major factor limiting growth in the production of tiles from either clay or shale was a low return on investment due to the small scale of most operations and other factors.[9]

Questionable quality of some clay tiles does not seem to have been a major issue in the industry's decline. Indeed, there continues to be more general uncertainty about the long–term durability of plastic tubing. Clay tile has a reputation for longevity, with many farm drainage systems still functioning after more than 50 years. Plastic tubing is much more vulnerable to improper installation. Its low strength requires that it be equally supported on all sides to prevent its collapse. Most clay tile producers can cite cases where unsatisfied farmers have replaced plastic tubing with clay tiles. Clay tile is less easily damaged by rodents, and is relatively unaffected by corrosive elements in soils and ground waters as compared to both plastic and concrete pipes.

Cost of production, handling and installation, is the main issue on which plastic pipe has competed so successfully with clay tiles. Compared with clay,

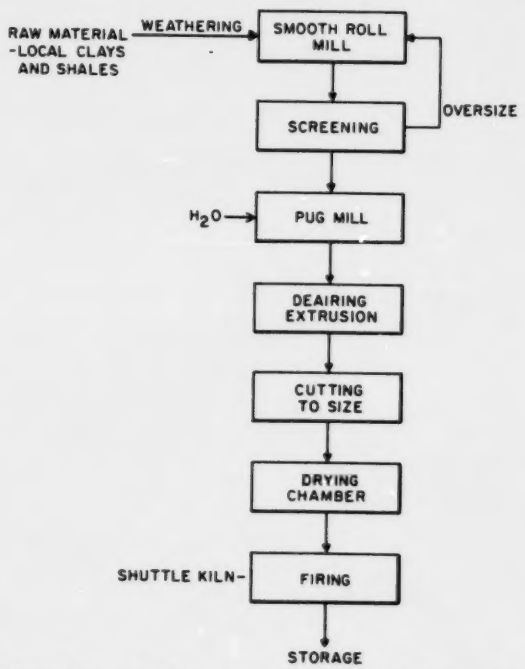

Figure 5.1 Process Flow Chart for drainage tile production.

the polyethylene raw material is very expensive, but its extrusion into thin–walled corrugated tubing requires little operating cost or capital investment.

Internationally, research into improving pipe material and the manufacturing process has been conducted in efforts to increase the competitiveness of the clay products.[12] Mechanization of the process has been found to reduce the costly labour requirements and minimize the quantity of rejects. The clay tile quality has been improved by finer milling, increased consideration of green densities and higher firing temperatures, all of which lead to a higher strength body. Improvements in the beneficiation of the clay to lower the volatile impurity content have allowed these higher firing temperatures and have reduced firing schedules to as low as 1 hour. The production of high quality tile under these demanding firing conditions has been realized by the advent of the roller hearth kiln.

Fuel is a major cost factor in the production of clay tile. The A. C. Martin plant at Parkhill did not have access to natural gas until 1985, and its conversion to gas–firing was not complete until the end of 1985. Their original oil–fired beehive kilns accounted for about 35 percent of their tile costs, but improved burning efficiency in a new box kiln (see Photo 5.4) reduced it to 30 percent. Gas firing was expected to reduce fuel costs to 25 percent of tile cost.

Some years ago, when oil costs were near their peak, Martin experimented with sawdust, using screw conveyors and pneumatic feed to the burners, and found it competitive with oil as it was then priced. However, the sawdust proved undesirably abrasive to the kiln refractory liners, particularly around the burner feed points. Even if that problem could be resolved, it is doubtful that sawdust could compete with lower cost natural gas. Nevertheless, burning of the tile proved equally effective with sawdust, and it was felt that there were no significant technical barriers to its use.

In 1985, both Martin and Dresden realized further economies by introducing a 3–1/2–inch (9 cm) tile which they claimed was at least equal in drainage capacity to 4–inch (10 cm) corrugated plastic tubing when the increased drag due to the corrugations affects the flow rate in the tubing. Martin's was made with a slightly thinner wall, resulting in an overall saving in weight of 6 pounds (2.7 kg) for a standard 4–inch tile and 4 pounds (1.8 kg) for the 3–1/2–inch. These are finding wide acceptance, particularly as they can be marketed at about the same price as plastic tubing (i.e. 24 cents per foot or 79 cents per metre in 1985). Furthermore, the ploughing technique used in laying plastic tubing, was adapted for use with clay tile and is reducing the previous 6 cents per foot (20 cents per metre) difference in installation cost. Indeed, Dresden claims to know contractors who would install either clay tile or plastic with no difference in installation cost.

In an effort to bolster lagging plant capacities, most clay tile producers have considered producing other clay products as well. And some have successfully converted to production of concrete pipes or plastic tubing. Bricks, wine racks, flowerpots, roofing tiles, sewer pipes, flue liners and floor tiles have all been considered as allied products to clay tile production. Inevitably, inferior surface clays have made these alternatives difficult to realize. But plants using shale have been encouraged by test runs for roofing tiles, chimney flues, and with certain additives, for a range of Mexican–style floor tiles. Additionally, a small market exists for crushed tile chips for use as decorative aggregate in gardening and landscaping.

PRODUCTION AND CONSUMPTION

Worldwide decline in production and use of clay drainage tile in favour of plastic tubing is primarily a function of price. The conversion is virtually complete in western European countries. The organic Fletton clays of England stalled the trend for a few years because they were nearly self–firing, and in 1978 their market share was still 80 percent,[4] while Ontario's clay tile had dropped to 19 percent. However, the U.K. production has declined rapidly since 1978.[8]

Table 5.4 traces the decline in production of clay drainage tiles in Ontario for the period 1975–1983. Interviews with tile producers in 1983 gave these reasons for the decline:[10]

1. depressed overall economy of the early 1980s, and low farm incomes;
2. polyethylene pipe is less expensive to produce, and is lighter in weight, easier to handle, install and store;
3. clay tile is subject to rigorous strength standards, while none exists for plastic pipe;
4. higher clay production costs for fuel, labour, machinery;
5. improved road network has resulted in overlapping market ranges; hence competition between producers;
6. smaller companies forced out by larger ones through lower unit costs;

TABLE 5.4 REGIONAL PRODUCTION OF DRAIN TILES MADE FROM CLAY OR SHALE.(11)
Numbers of 4-inch (10 cm) tiles or equivalents

County or RM	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Bruce	2,703,720	591,025	14,000							
Elgin						38,690	17,878		3,368	4,968
Essex	305,555									
Grey		1,320,000	1,048,000	1,330,000	1,330,000	1,180,000	1,140,000	1,050,000	921,640	
Halton	1,019,660	812,584		55,984	56,000					
Hamilton-Wentworth	2,430,900	1,410,489	939,800	1,089,937	614,660	568,290				
Huron	385,000									
Kent	9,343,170	4,627,051	3,629,356	2,455,550	2,935,768	4,283,605	2,791,616	1,866,491	1,776,745	1,812,057
Lambton	3,731,835	4,241,862	3,586,724	3,662,426	3,975,768	2,831,958	1,548,581	1,172,380	1,103,796	544,395
Lennox & Addington		367,167	233,000	84,000						
Middlesex	3,893,195	3,961,458	3,383,220	3,475,863	6,711,273	3,926,255	4,373,379	3,387,075	3,977,000	3,133,226
Oxford	855,725	840,104	415,774	460,000	450,000	506,184	93,500	621,724	763,482	732,603
Peel	1,620,000									
Renfrew	1,371,600	1,168,558	1,166,700	1,025,584	1,025,000					
Waterloo	2,761,644	3,018,500	2,784,400	2,819,000	2,622,000	2,331,000	2,373,666			
Wellington	4,532,000	4,850,000	4,020,720	4,549,464	2,377,884	2,801,211	3,477,324	3,823,543	4,041,768	3,844,065
	34,954,004	27,208,798	21,221,694	21,007,808	22,068,353	18,467,193	15,815,944	11,921,213	12,587,799	10,071,314

7. several unusually wet springs have made access to fields difficult for tiling before cultivation, the peak tiling period;

8. additional costs of complying with *Pits and Quarries Control Act*;

9. delays induced by Ministries of Labour and Environment over minor infractions.

Other reasons mentioned during interviews in 1985, when the market for plastic tubing was also in decline, was a general belief in a saturation effect: that a large proportion of the lands owned by the more progressive farmers had already been tiled. Clay tile producers also felt that there was insufficient recognition of the fact that smooth-walled clay tiles provided better drainage than corrugated plastic, and hence cost savings that might have resulted from increased row spacing have not been realized. However, the current trend to a less expensive 3-1/2-inch clay tile, said to have the same drainage capacity as 4-inch tubing, should accomplish the same result.

For urban drainage projects in new subdivisions and shopping malls, most municipalities now specify PVC pipe in 6 to 12-inch (15-30 cm) diameters because of ease of installation.

In 1983, 4-inch plastic tubing was selling for about 16 cents per foot, and 4-inch clay tile 24 to 27 cents. But by 1985, plastic prices had increased to about 23 cents and clay tile to 28 cents. With the new 3-1/2-inch clay tiles selling for 24 cents, and the more efficient plough technique for clay tile installation, clay tile drainage systems in 1985 were closely cost-competitive with plastic tubing.

Annual surveys of manufacturers by mailed questionnaires during the years 1978-1981 inclusive received about 90 percent response with results as shown in Table 5.5. A continued high level of demand for plastic drainage tubing is obvious, at the gradual expense of clay tiles, while concrete tiles dominate the limited market for larger sizes.

Figure 5.2 shows the location of drainage tile producers, active in 1985 or recently closed.

PRODUCERS

GEORGE COULTIS AND SON LIMITED

Drainage tile has been produced at a plant just north of Thedford for many years, but in 1985 the company was reported to be dismantling its clay-working equipment. Soft Arkona shale from an adjoining pit in the valley of Decker Creek has been the raw material used. The plant is in lot 23, con-

TABLE 5.5 DRAINAGE TILES AND TUBING SOLD IN ONTARIO (NUMBER OF UNITS).

	Tile Diameter (inches)	1981	1980	1979	1978
Clay or Shale	4	18,126,392	20,795,259	21,069,856	24,080,885
	5	143,653	474,723	481,778	978,600
	6	548,255	975,379	1,019,069	1,458,715
	7	4,196	29,141	31,659	21,607
	8	221,832	338,741	393,193	352,846
	10	20,472	45,459	43,247	76,745
	12	5,100	12,434	9,924	18,157
		19,089,900	22,671,136	23,048,926	26,987,555
Plastic	4	127,784,386	122,736,949	103,477,136	106,105,272
	6	5,889,389	5,892,513	3,911,425	4,257,604
	8	867,069	666,757	594,137	790,787
		134,540,844	129,296,219	107,982,698	111,153,663
Concrete	6	231,510	261,532	385,687	328,300
	8	315,946	331,342	481,747	380,820
	10	319,452	177,023	404,239	359,622
	12	232,465	270,464	307,875	319,378
	14	168,708	194,485	163,416	512,609
	16	130,109	110,504	94,209	126,436
	18	116,264	122,992	94,659	90,935
	21	59,364	74,636		66,476
	24	54,048	55,140		39,238
		1,627,866	1,598,118	1,931,832	2,223,814
Undivided*		2,087,607	1,601,553	1,113,599	979,189
Total		157,326,217	155,267,026	134,077,655	141,344,221

*Undivided as to size or raw material

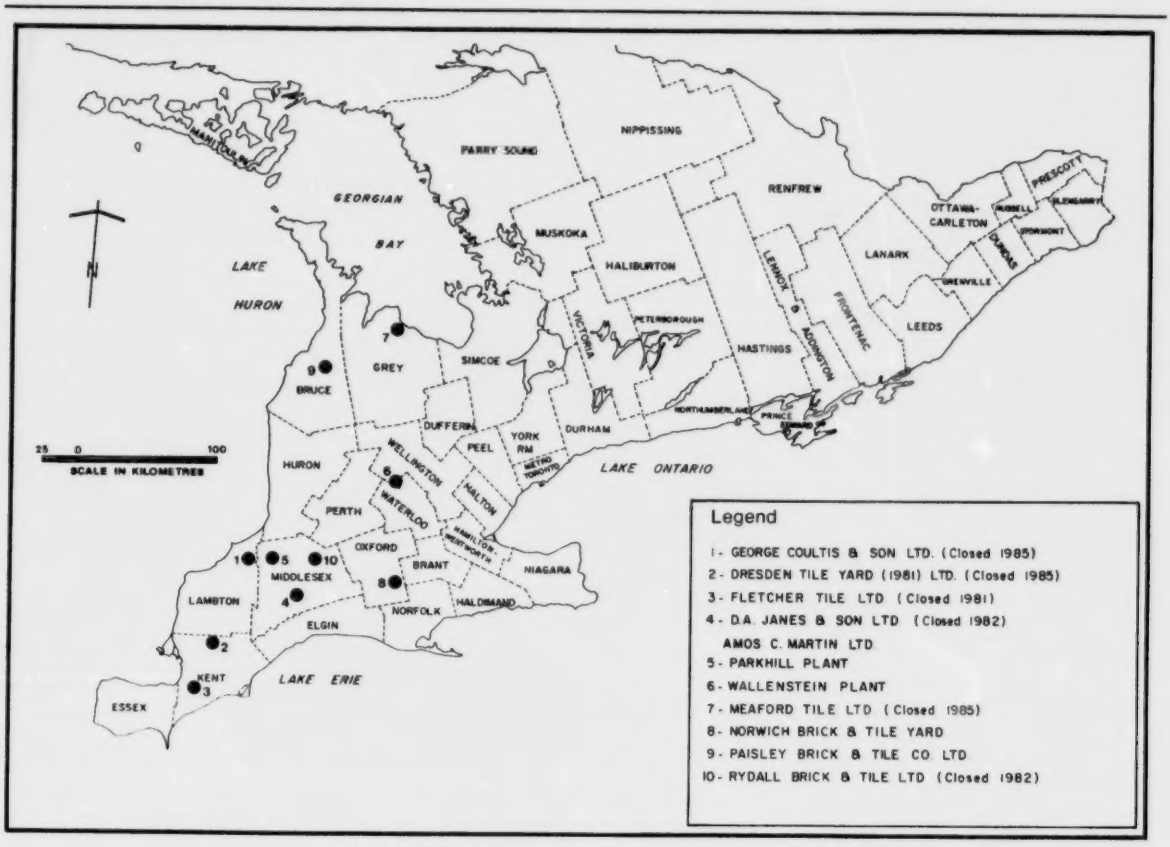

Figure 5.2 Ontario drain tile producers, active in 1981–1985.

cession III, Bosanquet Township, Lambton County. Descriptions of earlier operations are given by Baker,[1] Keele,[6] Montgomery,[7] and Guillet.[3]

The soft Arkona shale was occasionally worked over in the pit to expose it to the benefits of natural weathering before feeding it to a Parkhill pug feeder. Barium carbonate was added for scum control and the clay stream was conveyed to the plant and discharged through a Steele rolls disintegrator to a Parkhill pug mill. A Steele smooth–faced roll crusher preceded an F–R–H Hummer extruder.

Tiles were stacked in three tiers on rail cars and subjected to natural drying on 58 shed–covered drying tracks, each track holding 24 cars of 96 tiles. Burning was accomplished in four beehive kilns, two wood–fired and two oil–fired. Each had capacities of 16,000 to 20,000 tiles.

With an annual capacity of 2 million tiles, production in recent years had declined to just over 1 million.

DRESDEN TILE YARD (1981) LIMITED

Since 1907 drainage tile had been made in Dresden, Ontario. However, in spite of numerous innovations and modernizations over the years, the company announced its closure in September 1985 because of poor sales. The plant is located 1.5 km north of Dresden on the east side of Highway 21. It was purchased by D. J. McCaughrin in 1946, and in recent years was managed by his son.

The plant has an adjoining clay pit with a 2 m section of silty clay, somewhat leached of lime in its top 0.5 m, as the principal clay source. This clay burns to a uniform, fairly dense and hard salmon–red body of good quality. The operation is located in lots 7 and 8, concession V Gore, Camden Township, Kent County. Descriptions of earlier operations are given by Montgomery[7] and Guillet.[3]

In recent years tiles were produced in 4, 5 6 and 8 inch (10, 12, 15 and 20 cm) diameters by extrusion using a Steele 40 auger machine. In 1967 the company installed a Harrop tunnel dryer and tunnel kiln, the first and only such installation in the

history of Ontario drainage tile. Both were gas–fired, the dryer holding 21 cars containing 540 (4–inch) tiles per car. Cars moved directly from dryer to kiln, one every 40 minutes at maximum capacity. The plant was capable of an annual capacity of 7.5 million tiles, normal production being 20 to 25 cars per day, 150 per week.

In 1967 the company produced 5.5 million tiles (in 4–inch equivalents) and was anticipating increased annual sales. In 1975 the four original beehive kilns were in use as well as the tunnel kiln, but by 1981 the tunnel kiln alone was adequate for the reduced demand. In 1983 about 2 million tiles were produced in a sluggish market, and the following year 10–inch tile and wine bottle racks were added to production. Tile making in 1985 was restricted to May through August when a little more than 1 million tiles were produced, including a new 3–1/2–inch tile. When less than half of these had been sold by October, the company announced its permanent closing. About 25 people had been employed during the production period, including the company's own truckers for tile deliveries.

FLETCHER TILE LIMITED

This plant, built in 1912, has been owned by R. C. Cook since 1964 but has not produced clay tiles since 1981. Located at Fletcher, the plant and its adjoining clay pit is in lot 1, concession VIII, Tilbury East Township, Kent County.

Fletcher Tile now produces concrete tiles exclusively, in sizes greater than 8 inches. However, prior to closing its clay plant, it experimented with the production of 3–inch (7.5 cm) tiles for soil sterilization in greenhouses, also with hexagonal and ribbed tiles, and with wine racks.

The clay pit at Fletcher was extensive but shallow. Typical of much of Essex and Kent Counties, a thin stoneless layer above a silty grey till was the result of wave action in a post–glacial lake. Clay for tile making was excavated to a depth of 1 m, the thickness of the stone–free zone. It was relatively low in lime content, and burned to a hard red body of good quality at a moderate temperature.

Descriptions of previous operations of the plant and of the clay are given by Montgomery[7] and Guillet.[3]

D. A. JANES AND SON LIMITED

Located on the north side of Highway 2, 3 km west of Delaware and about 20 km west of London, this plant has not produced drainage tiles since 1982, but is capable of renewed production if the market improves. A thick section of buff–firing calcareous clay is available in an adjoining pit. The company has diversified into sales for plastic pipe, coal, wood and maple syrup. The clay tile equipment is old but in good condition. Burning is accomplished in two round gas–fired downdraft kilns. About 500,000 tiles could be produced with a work force of ten during an 8–month season.

Descriptions of tile making at this site are given by Baker,[1] Montgomery[7] and Guillet.[3]

AMOS C. MARTIN LIMITED

Amos C. Martin Limited operates two tile plants, at Wallenstein and Parkhill. The Martin family acquired the Wallenstein plant in 1919 and built the Parkhill plant in 1962. In 1985 the company introduced a 3–1/2–inch tile, and this is the principal product of both plants.

Wallenstein

The Wallenstein plant is in lot 20, concession I, Peel Township, Wellington County, 6 km west of Elmira. Tiles have been made on this site since 1888. Descriptions of earlier operations are given by Montgomery[7] and Guillet.[3]

Although a surface clay from a pit near the plant was used for many years, Queenston Shale from the Town of Halton Hills is now used exclusively. The quarry is worked on a slope using a bulldozer and ripper to expose the shale to natural weathering. Chemical composition of the top 2.3 m of soft leached shale and lower 2 m of harder shale, as exposed in 1982, is given in Table 5.6. Shale is trucked to the Wallenstein plant as required.

TABLE 5.6 QUEENSTON SHALE, GEORGETOWN QUARRY, AMOS C. MARTIN LIMITED. (2)

	Top 2.3 m Leached Shale (percent)	Lower 2 m Hard Shale (percent)
SiO_2	55.4	50.1
Al_2O_3	16.0	15.0
Fe_2O_3	7.50	6.96
CaO	4.36	7.85
MgO	3.50	4.21
Na_2O	0.21	0.20
K_2O	4.86	4.65

Analysis by X–Ray Assay Laboratories Ltd.

At the plant, shale is broken in a Parkhill double–toothed roll disintegrator and further ground in a J. C. Steele smooth rolls crusher. Oversize from dry screening is recirculated to the rolls crusher. The tile stream is extruded by an F–R–H Plymouth Junior auger machine and is cut by a Plymouth cutter and palletized for delivery to dryers by forklift.

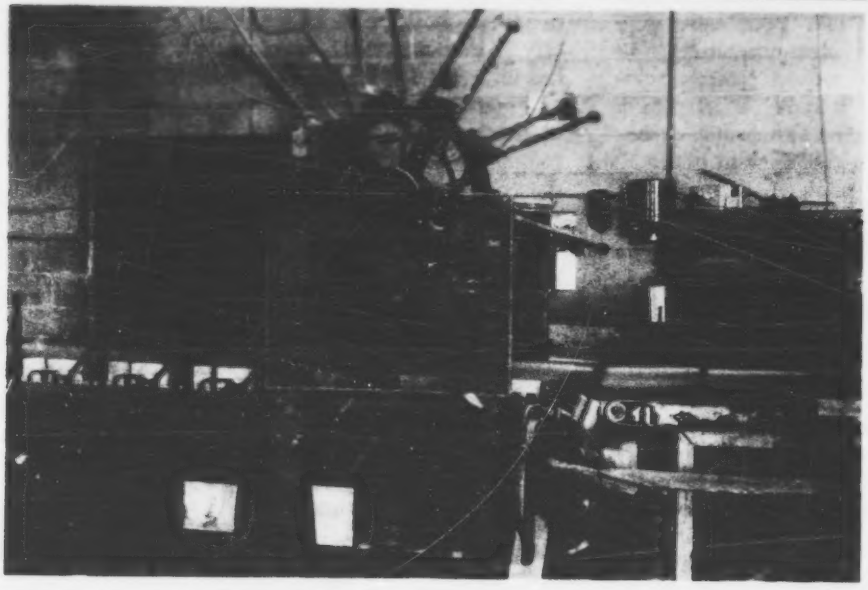

Photo 5.3 Automatic cutting of drainage tile. Photo courtesy Amos C. Martin Ltd.

Three waste–heat room dryers have a total capacity of 100,000 tiles. Drying time is on a 4–day cycle to a peak temperature of 95°C. Burning is accomplished in a gas–fired shuttle kiln with a capacity of 20,000 tiles. Burning cycle is 24 hours to a peak temperature of 980°C. Normal production is 100,000 per week of dense red perforated tiles.

About 5 million tiles are produced annually in 3–1/2–inch to 10–inch diameter sizes (9–25 cm). Forty people are employed year round.

Parkhill

The Parkhill plant was built in 1962 on the site of the former H. C. Baird soft mud brick plant. Originally using surface clays from the vicinity of the plant, Arkona Shale from Hungry Hollow is now used exclusively. The plant is located in lot 7, concession XX, West Williams Township, Middlesex County. The early Baird plant is described by Baker[1] and Montgomery,[7] and an earlier description of the Martin plant is given by Guillet.[3] A quarry on the south bank of the Ausable River (i.e. South Pit) in lot 22, concession VII, West Williams Township was opened in 1968. A second quarry (i.e. North Pit) in lots 22 and 23, concession IX, was acquired from the former Parkhill Brick Company in 1979.

The soft Arkona Shale is fed through a toothed roll which expels occasional limestone fragments before passing through an F–R–H smooth double–roll crusher. A Parkhill single–shaft pug mill precedes the F–R–H Plymouth Special extruder, and the tile stream is cut by an F–R–H wire–cutter (Photo 5.3).

There are three waste–heat room dryers, each with a capacity of 30,000 tiles. Drying time is 3 or 4 days. One beehive kiln, 8 m in diameter, is now seldom used. Instead, a single periodic box kiln (Photo 5.4) of the company's own design holds 32,000 tiles and is fired to a peak temperature of 1010°C on a production cycle that averages two kiln loads per week. Previously on oil, the plant was scheduled to be converted to gas in September 1985.

Twenty people are employed year round for an annual production of 3.2 million tiles in 3–1/2 to 10–inch (9 to 25 cm) diameters, 90 percent of which are perforated for improved soil drainage.

MEAFORD TILE LIMITED

In 1972, Continental Brick and Tile Limited abandoned its Shallow Lake facility near Owen Sound and constructed a new plant near Meaford on lot 12, concession III, St. Vincent Township, Grey County. Two parts of Queenston Shale from Owen Sound were mixed with one part Georgian Bay Shale from a quarry near the plant. In 1974 the property was acquired by N.S. Bauman of Wallenstein and the name was changed to Meaford Tile Limited. The plant was closed in 1985 because of weak demand for clay tiles and unfavourable research into the possibility of producing roofing tiles.

After 1974, drainage tiles were made exclusively from local grey shale obtained from a quarry

adjacent to the plant. Here, a 10 m section of Georgian Bay Shale was exposed, comprising the lower part of the Humber Member. The shale was trucked to covered storage at the plant, crushed to 16 mesh and conveyed to silo storage. The tile stream was extruded and wire–cut. Tiles were dried for 2 days in a room heated by waste heat. Firing was accomplished in a gas–fired shuttle kiln to a peak temperature of 980°C.

Typical annual production was 1 to 2 million using a work force of six for an 8–month season.

NORWICH BRICK AND TILE YARD (1979)

A tile yard 3 km northwest of Norwich has been in operation for more than a century, and has been owned by Dorothy and Henry Kleen since 1979. The clay pit and plant are in lots 12 and 13, concession III, North Norwich Township, Oxford County. Descriptions of earlier operations are given by Baker,[1] Montgomery[7] and Guillet.[3]

Laminated clay and silt deposited from ponded waters during retreat of the Port Stanley Ice is excavated to a depth of 3 m in a pit adjoining the plant. It is fed into a Parkhill pug feeder followed by a double conical rolls crusher and another Parkhill pug mill. Tiles are extruded by a Brewer auger machine and are cut by an F–R–H cutter.

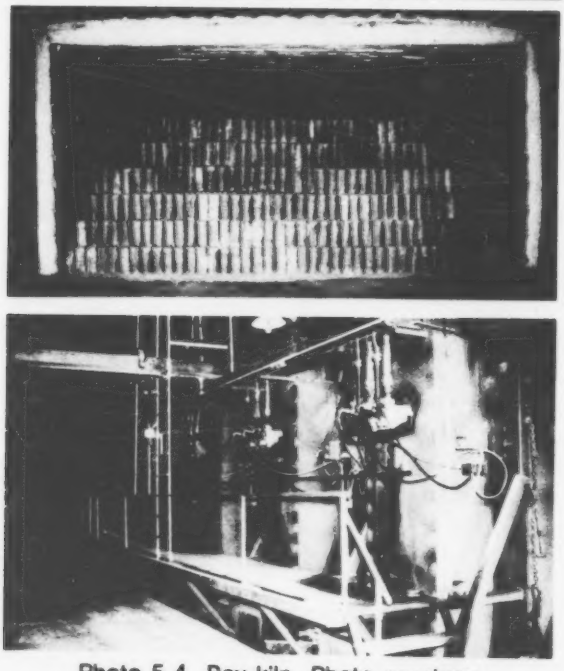

Photo 5.4 Box kiln. Photo courtesy Amos C. Martin Ltd.

There are eight open–air drying sheds having a total drying capacity of 90,000 tiles. Average drying time is 7 to 10 days. Two beehive kilns of 8 m diameter hold 22,000 tiles each. They are gas–fired to a peak temperature of 1000°C on a 4–day burn cycle, two days "steaming" and two days "burning". Turnover cycle for the kilns is about 8 days, giving a production of 35,000 tiles per week. Annual production in recent years has been about 700,000 tiles in 4 to 8–inch sizes (10–20 cm).

PAISLEY BRICK AND TILE CO. LTD.

Established as a producer of bricks in 1860, drainage tile has been the only product of Paisley Brick and Tile for many years. The plant was purchased by J. M. Seiler in 1948 and is managed today by his son, J. Douglas Seiler. The plant is located on the north side of the Saugeen River near the eastern limits of Paisley in lot 12, concession B, Elderslie Township, Bruce County. Descriptions of earlier operations are given by Baker,[1] Montgomery[7] and Guillet.[3]

Clay is obtained from an adjoining pit and stockpiled in covered storage. It is fed to the plant through a pug feeder, a smooth rolls crusher and a Parkhill pug mill before extrusion in an American Clay Machinery auger extruder. Tiles are cut from the extruded clay column by an F–R–H cutter.

Drying is accomplished in waste–heat room dryers. A single automatic oil–fired periodic kiln operates on a 4–day cycle, and a beehive kiln provides extra capacity when needed. Gas is not available.

Annual production is normally about 1.2 million cream–coloured tiles.

RYDALL BRICK AND TILE LIMITED

This plant was located at Elginfield, 20 km north of London at the junction of Highways 7 and 4, in lot 17, concession XVI, London Township, Middlesex County. It was closed in 1982 and its equipment sold at auction. Descriptions of its operations are given by Montgomery[7] and Guillet.[3]

Originally based solely on buff–firing clay from a pit behind the plant, in recent years the clay was mixed with Queenston Shale to improve the quality of the product. By itself, the local clay produced a rather soft, porous body on firing because of its high carbonate content. Making use of this feature, the company experimented with a crushed fired product of high porosity for kitty litter, but it proved heavy and dusty compared to established products made from Fuller's Earth. Other products evaluated were sewer pipe, roofing tile and floor tile, but even with

the addition of one-third Queenston Shale, porosities were too high for these uses.

The plant was capable of producing 2 to 3 million tiles annually with a work force of 22.

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Chapter 6 — Sewer Pipe and Flue Liner

INTRODUCTION

Sewer pipe production in Ontario has been largely associated with a single company since the industry's beginnings in the last century. The Toronto and Hamilton Sewer Pipe Company was established by the New family in Hamilton about 1860. In 1928 it was merged with three others to form the National Sewer Pipe Company Limited under Ryland New as president. Those three other companies were: the Ontario Sewer Pipe and Clay Products Company, started at Mimico in 1892; the Dominion Sewer Pipe Company, started at Aldershot (Burlington) in 1904; and the Dominion Sewer Pipe Company, started at Swansea in 1905.[6]

Today (1985), Kelly New, Ryland's son, is president of National Sewer Pipe Limited. Only the company's subsidiary, Canada Vitrified Products, established in St. Thomas in 1934, continues to operate in Ontario, producing clay flue liners and plastic drainage tubing, but only minor clay sewer pipe. The company's main production facility for clay pipe was in Clarkson, built in 1957 to replace the Swansea plant; production ceased, however, in 1981. The plants in Aldershot and Mimico had been previously closed. The Hamilton plant was converted to brickmaking in 1963, and was closed in the late 1970s.

The early sewer pipe industry in Ontario was founded on two small deposits of red plastic clay located at Aldershot (Burlington) and west Hamilton. These clays were almost stoneware quality, and they owed their value to an origin restricted to nearby terraces of eroding Queenston Shale on the lower flanks of the Niagara Escarpment. In both cases the clay beds were less than 400 m wide, 5 km long and generally less than 2 m thick. A low lime content, resulting from the leaching and weathering of red Queenston Shale, was the principal reason for its superior quality. Remnants of the Hamilton deposit have long since been lost to urbanization; the Aldershot deposit to Highway 403.[4]

National Sewer Pipe Limited still owns important reserves of Queenston Shale on the east side of King Road north of Highway 403 in Burlington. While under constant threat of sale or expropriation for municipal landfill purposes, these lands are an essential source of shale for the company's St.

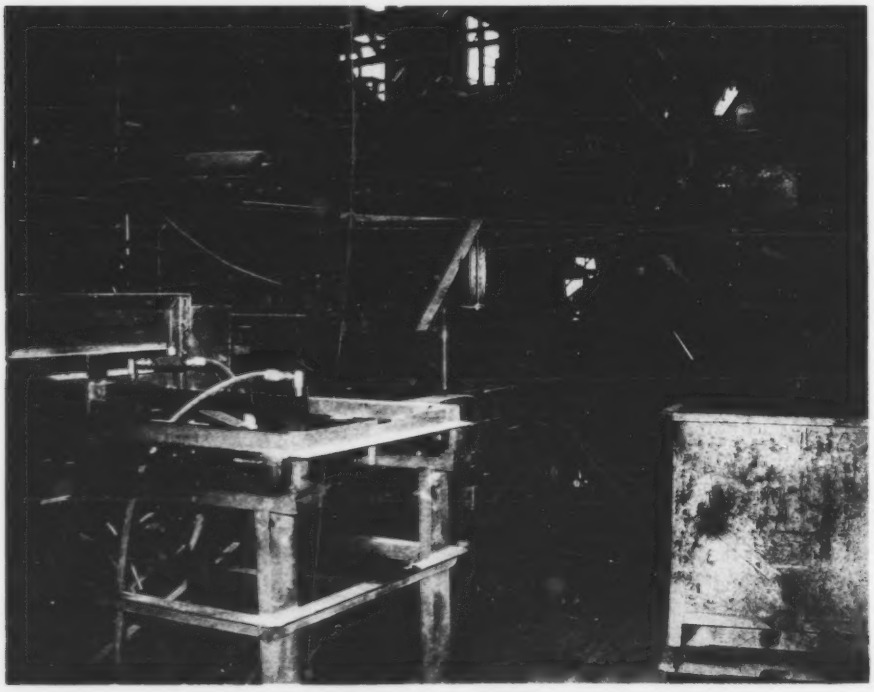

Photo 6.1 Flue liner extrusion at Canada Vitrified Products Ltd., St. Thomas. Photo courtesy B.H. Feenstra.

Thomas subsidiary. Also dependent on it are Halton Ceramics Limited, the only Canadian producer of clay flowerpots and filtration tiles, and Hamilton Brick Limited. The shale section exposed in these quarries is unusually favourable for vitrified clay products because of a lower lime content than is average for the Queenston Formation.[3] It is important, therefore, to preserve at least some of these lands for the industries dependent on the shale.

Earlier descriptions of the sewer pipe industry in Ontario are given by Baker,[2] Montgomery[6] and Guillet.[3] The Hamilton and Aldershot clays on which the industry was founded are described by Keele[5] and Guillet.[4]

TECHNOLOGY AND ECONOMICS

The clay requirements for sewer pipe are more stringent than those for most other heavy clay products. Sewer pipe clays must be plastic and tough, have a high green and dry strength, and vitrify to a strong dense body of low permeability. A long vitrification range and a high resistance to warping is desirable. Small deposits of red surface clay derived from weathered Queenston Shale at Aldershot (Burlington) and Hamilton were the only suitable sewer pipe clays in southern Ontario, and these have long since been depleted or lost to urbanization. Their principal asset was a low lime content, the result of leaching during erosion and transportation from a nearby source of Queenston Shale.

In spite of the favourable quality of these clays, glazing of sewer pipes was necessary to lower permeability through the walls. Indeed, this was common practice in many parts of the world, due mainly to the uneven firing characteristics of existing kiln technology.

Salt glazing was standard in the industry from early times, and was accomplished by throwing shovelfuls of rock salt onto the coal or wood fires near the end of the burning cycle in the beehive periodic kilns then commonly used. For a few years subsequently a ceramic glaze replaced the salt glaze, but by the early 1960s no glaze was applied at all. Improved kiln design and firing technology had resulted in greater vitrification and hence denser, stronger and less permeable clay bodies.

Advanced sewer pipe technology fortunately coincided with the final depletion of the red sewer pipe clays at Aldershot, making it possible to use the more limey and less plastic Queenston Shale mixed

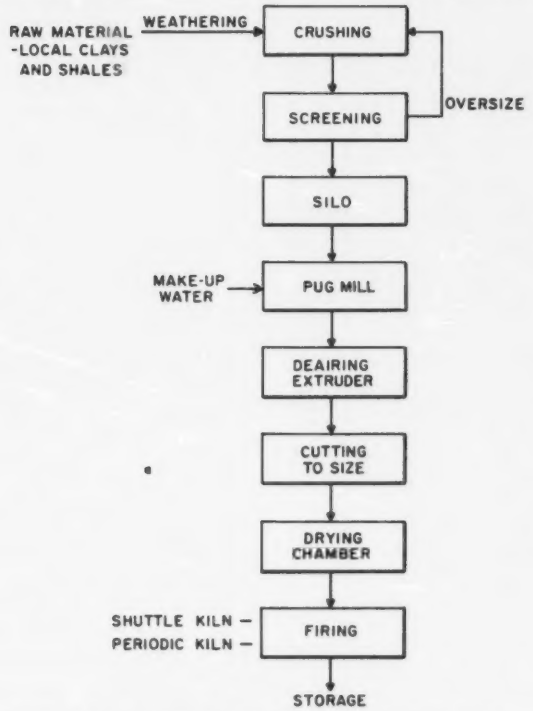

Figure 6.1 Process flow chart for sewer pipe and filter tile production.

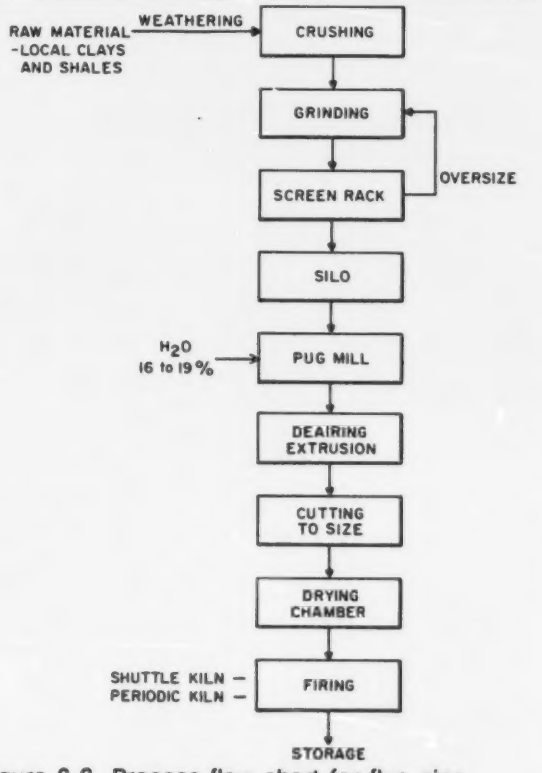

Figure 6.2 Process flow chart for flue pipe production.

TABLE 6.1 TECHNOLOGICAL IMPROVEMENTS IN HEPWORTH SEWER PIPE.(7)

	Pre-1960	1960-1980	Post 1982
Firing Time	7 days	2 days	1 hour
Strength(MPa)	15	25	50
Energy Consumption (kWh per metre of pipe)	50	25	10

TABLE 6.2 STANDARD SPECIFICATIONS FOR SEWER PIPE.(1)
Minimum Crushing Strength (3-Edge Bearing Strength)

	Extra Strength Vitrified Clay Pipe		Standard Strength Vitrified Clay Pipe		Perforated Vitrified Clay Pipe Extra Strength		Standard Strength	
Nominal Size, in.	lbf/linear ft	kN/linear m	lbf/linear ft	kN/linear m	lbf/linear ft	kN/linear m	lbf/linear ft	kN/linear m
3	2000	29.2	–	–	–	–	–	–
4	2000	29.2	1200	17.5	1250	18.2	1000	14.6
6	2000	29.2	1200	17.5	1600	23.4	1000	14.6
8	2200	32.1	1400	20.4	1600	23.4	1000	14.6
10	2400	35.0	1600	23.4	1600	23.4	1100	16.1
12	2600	37.9	1800	26.3	1800	26.3	1200	17.5
15	2900	42.3	2000	29.2	2200	32.1	1400	20.4
18	3300	48.2	2200	32.1	2640	38.5	1700	24.8
21	3850	56.2	2400	35.0	3100	45.2	2000	29.2
24	4400	64.2	2600	37.9	3520	51.4	2400	35.0
27	4700	68.6	2800	40.9	–	–	–	–
30	5000	73.0	3300	48.2	–	–	–	–
33	5500	80.3	3600	52.5	–	–	–	–
36	6000	87.6	4000	58.4	–	–	–	–
39	6600	96.3	–	–	–	–	–	–
42	7000	102.2	–	–	–	–	–	–

with imported fireclay. New extrusion machines, incorporating high pressure and de-airing features, did not require such plastic clays as before. The introduction of gas-fired tunnel kilns and improved periodic kilns gave better temperature control and more uniform heat distribution in the firing process.

Flow charts for production of sewer pipe/filter tiles and flue liners are given in Figures 6.1 and 6.2.

The market for vitrified clay sewer pipe has all but been lost to plastic and concrete pipe producers worldwide. However, through innovative techniques, one company in the United Kingdom has successfully reversed that trend. Hepworth Iron Company (Holdings) Ltd., a subsidiary of Hepworth Ceramic Holdings PLC, is by far the largest producer of vitrified clay pipe, consuming about 10,000 tonnes of clay per week at its two plants, and filling nearly 90 percent of the U.K. market for clay pipe. Pipes are produced in diameters from 4 inches to 40 inches (10–100 cm) using carefully batched raw materials, conventional tunnel kilns and a new advanced roller kiln.[7]

The roller kiln is much shorter than the conventional tunnel kiln. Pipes are rolled horizontally through it and individually fired at elevated temperatures for only 1 hour. Such rapid firing has required finer milling of the clay and computerized blending, plus pre-calcination to minimize the content of volatile impurities. The result has been greatly improved fuel efficiency and pipes of superior quality (Table 6.1).

Because of greatly improved strength, it has become possible to reduce the thickness of the pipe wall, thereby reducing raw material and energy consumption and weight of the finished pipe. Several innovative pipe-joining systems using polypropylene couplings have resulted in clay pipes being cheaper to install than plastic pipes which must be embedded in a granular cushion to prevent puncturing. Clay pipes now comprise about 80 percent of the total sewer pipe market in the U.K. Plastic and concrete pipes have higher energy requirements in their manufacturing, while the superior acid resistance of clay pipe gives it a further advantage in corrosive environments.[7]

SPECIFICATIONS

A published specification for standard strength sewer pipe is ASTM C 700[1]. The specifications are reproduced in Table 6.2.

Unlike drainage tile where product specifications are much less stringent and rarely enforced, sewer pipes must conform to a rigid set of specifications and require superior raw materials and carefully controlled manufacture. Principal concerns are strength, water absorption, acid resistance and tolerance limits for designated pipe sizes.

While drainage tile is deliberately porous, sewer pipes must be water–tight. Maximum water absorption through the walls is 8 percent, and plastic or rubber couplings are now standard jointing materials.

PRODUCTION AND CONSUMPTION

Statistics are scarce for sewer pipe production in plastic and concrete, but are well documented for clay. Table 6.3, from the Ontario Mineral Score 1981–1984,[8] indicates that the production of clay sewer pipe reached a peak of about 1.5 million metres in 1976–1977, then rapidly declined. Although concrete pipes were being produced in the late 1960s, the advent of cheaper plastic pipes in the 1970s was the principal reason for the decline in clay pipe usage.

TABLE 6.3 CLAY SEWER PIPE PRODUCTION IN ONTARIO.(8)

	Volume (metres)	Value (dollars)
1984	52,093	399,600
1983	64,286	331,071
1982	13,247	37,805
1981*	5,376	23,439
1980	407,399	1,777,691
1979	822,589	3,481,432
1978	1,316,285	4,314,289
1977	1,529,652	4,767,616
1976	1,582,621	4,413,478
1975	1,090,818	2,505,256

*National Sewer Pipe's Clarkson plant closed.

Since the closing of National Sewer Pipe's Clarkson plant in 1981, minor production of clay sewer pipe has commenced in the St. Thomas plant of Canada Vitrified Products Limited, but it is not expected to become a substantial product line for the company because of weak sales.

The annual Ontario market for sewer pipe is probably in the range of 1.5 to 2 million metres, mostly plastic but with substantial concrete pipe in the larger diameters. Less than 5 percent of this market is currently served by clay pipe. Annual production of clay sewer pipe is only 500 to 1,000 tonnes, compared with more than 600,000 tonnes in the U.K. where clay pipe predominates largely as the result of new cost–saving technology.

CANADA VITRIFIED PRODUCTS LIMITED

Canada Vitrified Products is the only remaining National Sewer Pipe clay manufacturing facility in Ontario. It produces mainly flue lining, with minor sewer pipe at 60 Burwell Road in St. Thomas, but it also produces plastic drainage tubing in diameters of 4 and 6 inches (10 and 15 cm). The company employs about 24 people in the production of their clay ware. National Sewer Pipe also has a plant on the south shore of the St. Lawrence River, east of Montreal, where flue liners, hollow block and plastic pipe are manufactured largely for export to the U.S.A.

The St. Thomas plant was opened in 1934, specifically to take advantage of inexpensive boat shipments of Pennsylvania clays through nearby Port Stanley on Lake Erie. It subsequently obtained both fireclay and shale from Ohio by rail, and more recently mixed these with red Aldershot clay which was trucked from Burlington, Ontario. In 1985 the main raw materials were red Queenston Shale from the company's Burlington quarries and Devonian shale of the Machias Formation from Alfred, New York, both received by truck. Machias Shale is of fireclay quality (Table 6.4). However, the company was experimenting with the use of Arkona Shale from the Amos C. Martin quarry near Arkona, instead of the more costly Alfred material.

The company is doing a brisk business in flue liners, its major market at present, but some clay sewer pipe is still produced. Flue liners are made from a mixture of 90 percent Queenston Shale and 10 percent Alfred Shale. Queenston Shale alone is too easily chipped during handling in either the green or fired state. Recent tests seem to confirm that Arkona Shale is equally as effective as Alfred Shale in reducing this problem. Flue liners are made in various sizes from 8 to 24 inches square (20–60 cm). Specifications for clay flue liner are given in the ASTM standard C 315–78C, which details the standard dimensions and acceptable tolerances.

Sewer pipes are made from a mixture of 60 percent Queenston Shale, 35 percent Alfred Shale and 5 percent Amabel Dolostone from Nelson Aggregate Co. in Burlington. The small addition of dolostone has been found effective in reducing water absorp-

tion in the fired product. Sewer pipes are produced in 4 to 12 inch (10–30 cm) diameters and in 4 and 5 foot lengths (120 and 150 cm).

TABLE 6.4 MACHIAS SHALE, ALFRED, NEW YORK.

Chemical Composition (%)	
SiO_2	58.4
Al_2O_3	18.7
Fe_2O_3	7.75
CaO	0.59
MgO	1.80
Na_2O	0.52
K_2O	4.26
TiO_2	1.00
CO_2	0.5
Ignition Loss	6.0
	99.6
Mineral Composition (%)	
Quartz	40
Calcite	nil
Dolomite	nil
Feldspar	<5
Hematite	1
Clay Minerals	
Illite	35
Chlorite	25

Source: Ontario Research Foundation

Raw materials are reclaimed from covered storage by front end loader and fed in the batch proportions to two drypans for grinding. Discharge from each drypan is collected in separate steel storage bins, one for flue lining and one for sewer pipe production.

Most products are produced by two F–R–H Junior double–shaft pugging and de–airing auger extruders (Photo 6.1), but a Bradley and Craven auger press is used for small fittings. The green ware are automatically loaded on pallets and transferred to drying rooms by forklift. Three room dryers, 14 m by 24 m, dry the green product using waste heat from the kilns augmented by gas.

Firing is accomplished in two new round periodic kilns and one rectangular shuttle kiln; also two older round downdraft kilns are used when needed. The two new round periodic kilns are the most efficient, each holding 75 tonnes of green ware and requiring 32 hours burning to a peak temperature of 1070°C. These kilns each feature ten burners at the top, the heat being drawn down by a fan in the exhaust stack. The shuttle kiln holds 41 tonnes of ware and is fired through 36 burners in a burning cycle of 35 hours. The older kilns are 9 m in diameter; each is equipped with 10 gas burners.

Rubber couplings and other accessories for sewer pipe are also made at the St. Thomas plant.

COMPETING MATERIALS

Like drainage tile, clay sewer pipe has significant competition from plastic in the smaller diameters, and concrete pipes in diameters greater than 12 inches (30 cm). Plastic pipes cost approximately the same to produce, but the capital investment is much smaller and there are savings in handling because of the lighter weight of the plastic pipes.

Canada Vitrified Products still manufactures a small amount of clay sewer pipe at its St. Thomas plant, but it is only a minor product, approximately 500 to 1,000 tonnes of pipe annually. Its major products are clay flue liners and plastic drainage tubing. In spite of a strong demand, the company elected not to produce plastic sewer pipes itself because of the rapid emergence of a number of new suppliers. At one time, however, its parent company, National Sewer Pipe, did produce concrete sewer pipes at another site in Ontario.

Large concrete sewer pipes can be made at substantial savings, approaching 50 percent the cost of equivalent clay pipes. In fact concrete pipes have controlled the market in the larger sizes for some years now except where exposure to corrosive chemicals, as in some industrial applications, may require the superior resistance of clay pipe. However, plastic pipes are threatening the market for concrete pipes also, because of on–site savings in handling and installation.

Plastic sewer pipes are made from thermoplastic polyvinyl chloride (PVC) in diameters generally 6 to 12 inches (15–30 cm) and in lengths to 20 or 30 feet (6–9 m). They are typically smooth–walled rigid pipes that are light in weight and sufficiently strong to provide easy handling and relatively inexpensive installation.

Whereas the cost of clay and plastic pipes may be similar, clay pipes represent a much more capital–intensive industry. Raw material costs for clay pipe represent only 10 percent of the finished product price, while feedstock for plastic pipes is approximately 80 percent of overall cost.

However, in the United Kingdom there is a trend towards traditional clay products, due both to aesthetics (in bricks and roofing tiles) and lower product and installation costs. The high efficiency of Hepworth's new roller kiln reduces the energy consumption for clay vitrification to about one–third of that required for making Portland cement.[7]

Vitrified clay flue liners are facing increasing competition from insulated steel pipe, a more easily

installed and less expensive chimney system than traditional masonry units.

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Chapter 7 — Expanded Aggregate

INTRODUCTION

The use of low density materials in concrete has been practiced since ancient times. The dome of the Pantheon in Rome is known to have contained pumice and pozzolana. Although it is probable that brick and tile fragments were used as aggregates throughout the history of concrete production, it was not until 1918 that a method of producing lightweight aggregate from shale was patented in the United States[49] by S. J. Hayde.

The purpose of using lightweight aggregates in modern concrete is to reduce its weight and improve its thermal and acoustical insulation properties.

The term *lightweight aggregate* refers to materials of a number of types,[17] the most important being the following:

- vermiculite,
- perlite,
- pumice,
- diatomite,
- zeolites,
- expanded clay, shale or slate,
- furnace clinker from stolier boilers
- sintered fly ash,
- bottom ash,
- foamed or pelletized blast–furnace slag.

The demarcation between normal weight and lightweight aggregate is somewhat arbitrary. In Europe it is common to describe materials with density less than 880 kg/m^3 (55 lb/ft^3) as "lightweight".[56] In North America the maximum unit weight of lightweight aggregate is set at 1040 kg/m^3 (65 lb/ft^3) for combined coarse and fine materials.

Although it is common for expanded vermiculite and perlite aggregates to be ultra–light with densities as low as 80 kg/m^3 (5 lb/ft^3), these materials have minimal compressive strength and their use is limited to non–structural applications. In concrete or highway applications, structural strength is required, and thus materials in the density range 640 to 960 kg/m^3 are used. In general, this class of lightweight aggregates is manufactured from the following materials:

- clay, shale or slate,
- slag,
- fly ash.

This chapter is principally concerned with expanded aggregates made from clay, shale or slate, although some consideration must be given to competing products made from fly ash or slag. In the following discussion of these materials, the issues of raw materials, process methods, properties and the history and future of the Canadian and Ontario lightweight aggregate industry are considered.

THE MANUFACTURE OF LIGHTWEIGHT AGGREGATES

RAW MATERIALS

Lightweight aggregates are generally cellular materials, formed by the entrainment of gases in a cooled molten or semi–molten mass. A number of approaches can be used to produce such materials, depending largely upon the available raw materials.

Two types of expanded product can be produced. The preferred type is a sealed aggregate, consisting of cellular pellets; the other is an open cellular crushed clinker product. Both are extensively used in making concrete blocks which are 30 percent lighter in weight than normal blocks and twice as effective as insulators for heat and sound. Because they are less porous, coated aggregates are more easily mixed with water and cement in the concrete batch.

Some clays, shales or slates will bloat or expand when heated. To the manufacturer of brick, this is an undesirable property and must be prevented. The origin of bloating has been investigated widely (see references 36, 6, 31, 52, 27, 16, 23, 55, 9, 53, 50). In general, a clay body requires two qualities for bloating to take place:

a. when it is heated to a temperature of incipient fusion, gas must be formed;

b. when heated further, the glass produced at fusion must be of sufficient viscosity to entrap the gases formed.

In brickmaking, the selection of raw materials and the rate of heating are deliberately controlled to avoid these conditions. In making expanded aggregates, these qualities are optimized.

Low density masses can be formed by cooling molten glassy materials. In the operation of some coal–burning furnaces, foamed clinkers are formed. These, together with fused bottom ash from more modern power plants, are widely used in Europe as heavy and medium grades of lightweight aggregates.

Blast furnace slag can be foamed or pelletized to form excellent lightweight aggregates. Such materials are in common use in Europe, the United States and Ontario.

An alternative approach has been to sinter pellets of fly ash. Aggregates of this type are produced in Europe under the name Lytag™. Mixtures of fly ash and shale may be sintered (Taclite™) or mixtures of shale and clay can be bloated (Aglite™). According to Fleming[17] all of these approaches were being applied in Britain in 1976, but at that time Lytag™, with its sintered fly ash, appeared to be leading in penetration of the structural concrete market.

In Ontario, three approaches have been taken to the production of lightweight aggregates:

- expansion of shale,
- pelletization of slag,
- sintering of fly ash.

As is discussed elsewhere in this report, the only lightweight aggregate presently produced in Ontario is made by pelletizing blast furnace slag. All other Canadian production is from clay or shale.

Clays and Shales for the Manufacture of Expanded Aggregates

It has been generally considered that not all clays and shales are suitable for making coated aggregates. The required characteristics are outlined by Wilson[54] as follows.

> "It (the raw material) must contain a combination of fluxes that will develop a viscous glass when heated to a point of incipient fusion. Also it must contain a mineral or minerals that will dissociate when the material is in the viscous state and release a gas or gases. If these conditions exist, the gases will be entrapped within the glass formed, and the particles of clay or shale will expand or bloat. The raw materials should also have a fairly wide vitrification range in order that the temperature fluctuations within the kiln will not have too marked an effect on the product. It is difficult to maintain the temperature within limits of less than about 50 degrees. One of the troublesome components of clays and shales, particularly those found in Ontario and Quebec, is lime in the form of calcite. A small quantity is desirable, for it acts as both a flux and a gas-producing agent. In larger quantities, however, the fluxing action is excessive and a small increase in temperature above that at which vitrification has begun will result in extensive fusion. This is caused by the formation of glass of low viscosity."

Chemically, the raw materials for lightweight aggregate production can range considerably in composition between the following:

Oxide	*Mass Percent*
SiO_2	50–80
Al_2O_3	10–25
Fe_2O_3	3–10
CaO	0–3
MgO	0–5
K_2O	1–10
Na_2O	0–5
SO_3	0–1.5
Loss in ignition	4–8

To the extent that the basic requirements are met for bloating and gas retention in the partly fused mass, the exact composition is not critical and can be adjusted by the use of additives to induce bloating or control fluxing capabilities.[15] Typical bloating agents are alkali or alkaline earth lignosulphonates, flour and sodium carbonate.

Special processing needs and problems have been discussed by Wilson.[58] If a clay material is too soft or finely divided, it may have to be pelletized by a disc pelletizer or extrusion machine prior to firing. If pelletizing is necessary, improved bloating can sometimes be achieved by adding also a gas-producing material, such as lignosulphonate or waste oil, to the pellet batch.

A number of clays and shales in Ontario show promise of being suitable for expanded aggregate production. In particular, the shallow stoneless clays of Essex and Kent Counties in southwestern Ontario are almost everywhere satisfactory for coated aggregate in a rotary kiln process. So too are the shales of the Georgian Bay, Blue Mountain and Cabot Head Formations and the Hamilton Group.

H. S. Wilson[54] has reported extensively on Ontario clays and shales. Table 7.1 is a summary of his technical data for those clays and shales which show promise for production of coated aggregate by the rotary kiln process. Such clays and shales bloat over a sufficient temperature range below their agglomerating temperature that they should be workable in a commercial process. Their bulk densities and crushing strengths are generally comparable to that expected of commercial products.

Table 7.1 also includes Queenston Shale, which bloats in a narrow temperature range too close to the agglomerating temperature for rotary kiln use, but along with many other Ontario clays and shales might be suitable for a sintering process. Bloating is not necessary and should not be excessive for effective sintering.[54]

TABLE 7.1 BLOATING CHARACTERISTICS OF SOME ONTARIO CLAYS AND SHALES.(54)

Raw Material	Location	Bloating Range (°C)	Expansion (%)	Bulk Density (kg/m³)	Crushing Strength (MPa)
Blue Mountain	South of Little Current, Manitoulin Island	1090–1120	100	530 –580	3.3 –16.8
	Duffins Creek, Pickering	1090–1115	90	640	3.2–11.8
Georgian Bay Shale	Ottawa East		175	820	strong
	Leitrim, South of Ottawa		good		
	Ottawa Southeast		100	660	
	Ramsayville, East of Ottawa	to 1115	25–180	460–980	2.2 –14.5
	Erindale	1100–1125	100	590	3.5–13.2
	Mississauga	1090–1115	135	525	2.4–9.5
	Don Valley, Toronto	1080–1105	75–100	530 –655	low
	Mimico	?–1110	30–100	575–815	2.2–7.2
Queenston Shale	Grimsby		good		
	St. Catharines	1190–1210		590 –655	7.4–10.2
	Cheltenham		good		
	Streetsville		good		
	Burlington		good		
Cabot Head Shale	Stoney Creek	1100	75	655–785	7.2–7.8
Arkona Shale	Thedford	1110–1150	70–80	560–625	2.4–17.6
Eastern Ontario Clays	Ottawa south	1090–1105	35	760	2.7–10.9
	Collins Lake, North of Kingston	1070–1095	115	405	1.7–4.9
	Cornwall		10–20	640–785	1.1–4.5
	Prescott	1115–1140	55	595	1.9–5.3
	Cumberland	1095–1115	25–35	720–790	5.0–40.1
Southwestern Ontario Clays	Chatham	1100–1140	75	565	2.1–2.4
	Coatsworth	1050–1065	30	735	3.9
	Dresden	1105–1140	40	735	4.1–19.0
	Fletcher	1100–1130	85	505	3.2–12.9
	Tilbury	1105–1140	65	555	3.8–13.6
	Tupperville	1075–1130	55	600	5.0–19.3
	Lambeth	1100–1120	45	755	4.2–20.3
	Wallenstein	1080–1115	120	490	2.3–8.2
Northern Ontario Clays	Rydal Bank, 60 km east of Sault Ste. Marie	1075–1100	35	890	5.3–35 7

The range of crushing strengths for expanded aggregates in Table 7.1 generally reflect the pressures required to compress the aggregate 2.5 cm and 5 cm when placed 12.7 cm deep in a steel cylinder of 7.6 cm diameter. However, these results are for comparative evaluation of raw materials only, and final evaluation of aggregate strength must be made in tests of the resulting concrete.[19] Some work on aggregate evaluation has been published;[19,8,26,30,57] tests include mechanical strength properties, modulus of elasticity, and durability.

PROCESSES FOR THE PRODUCTION OF EXPANDED CLAYS AND SHALES

The technical literature on expanded clay and shale aggregates, and their production, is voluminous. In Canada, reports by H. S. Wilson[56,54,58,57,60] have been published by CANMET (Canadian Centre for

Mineral and Energy Technology), Department of Energy, Mines and Resources, Ottawa. H. S. Wilson has also reported extensively on expanded blast furnace slag. Recently, several patents, originating from Germany and the United Kingdom, have been granted on novel technology.[39,42,28,3] In addition, other recent publications discuss technological progress in expanded aggregate production.[62,34]

Expanded clay and shale are fired either in rotary kilns or by sintering. All Canadian plants, and the majority of those in the United States, use rotary kilns.[56] In 1976, Wilson reported that eight plants in the United States were using the sintering process.[56]

Of the 32 expanded aggregate plants now operating in the United States, only one, at Roanoak, Virginia, is currently using the sinter process. The earlier sinter plants all ceased production during the late 1970s.[38]

Whichever method of expansion is used, the production of expanded clay or shale aggregates (Figure 7.1) comprises the following basic steps:

- quarrying,
- preparation of raw materials,
- firing (heat treatment),
- preparation of aggregate–sized materials.

Each of these stages of production has been described in detail elsewhere.[56] In 1976 Wilson[56] estimated that 35 percent of the total cost of a plant to produce expanded aggregate was associated with the firing and dust collection equipment. In 1979, some 50 percent of the cost of production of Haydite in Mississauga was allocated to fuel. In view of this, it is not surprising that the main developments in process methods have been associated with firing and the energy efficiency of heat treatment. Because of the importance of this aspect of the production process, some consideration is given to it in this report. The published literature contains more detailed discussions of established processes and new innovations.[56,24]

With the demise of the sintering process (see above), the production of expanded aggregate in North America is overwhelmingly dominated by rotary kiln firing. Most of the plants are of an older type, and some general considerations can be made of their qualities and problems.

A rotary kiln in its simplest form comprises a tubular steel structure, mounted on rollers at a slight angle to the horizontal. It is lined with refractory insulation and is fired from one end by a burner fueled with gas, oil or coal. Raw material in a suitable form (for example as green pellets) is introduced at the end opposite from the burner. The kiln body rotates slowly, which action, combined with the slight gradient, causes the material to pass at a controlled rate through a thermal gradient. The rate of passage (retention time) may be modified by the use of flights, barriers, chains, changes in diameter of the kiln structure or trefoils.

As a heat exchanger, the rotary kiln is very inefficient; in some plants as little as 10 percent of the applied heat is actually used to bloat the material.[56] The remainder is lost through combustion gases and dust, radiation, and sensible heat in the discharged product.

By the introduction of internal structures and the recovery of heat from the discharged product, some improvement in efficiency can be attained. Wilson reports that the most efficient kilns (operating in 1976) consume approximately 2070 x 10^6 J/m^3 (approximately 1.5 x 10^6 Btu/yd^3). In 1975 Biege and Cohen[5] reported that some lightweight aggregate producers were consuming as much as 5 x 10^6 Btu/short ton, while plants using feed of low moisture content and employing heat recovery equipment (such as grate coolers) could produce at 2 x 10^6 Btu/short ton. For a product of 1040 kg/m^3

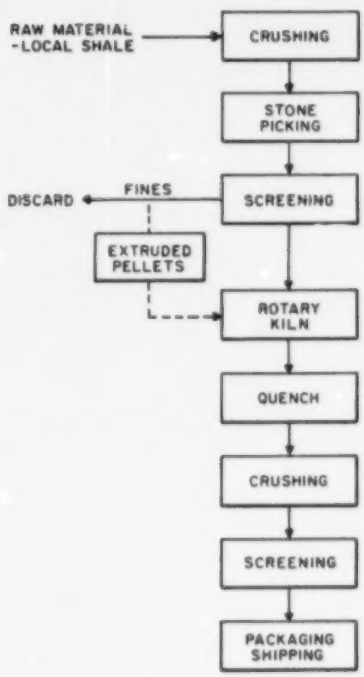

Figure 7.1 Process flow chart for lightweight aggregate.

(65 lb/ft^3) this is equivalent to a range of energy demand from approximately 6000 J/m^3 to 2400 J/m^3. Literature currently being supplied by the GATX–Fuller company[15] claims that most lightweight aggregates can be produced at or below 2 x 10^6 Btu/ton (approximately 2400 J/m^3) by the use of coolers and kiln 'internals'. Such kilns are reported to be in widespread use by the U.S. industry[15]. Energy requirements as low as 1.8 x 10^6 Btu/ton (~2160 J/m^3) have been attained for material of 40–45 pcf (642–722 kg/m^3).[15]

In spite of these advances, the rise of energy costs, especially during the 1970s and early 1980s, has caused considerable problems for the expanded clay and shale industry. In 1982, 85 percent of the U.S. industry surveyed by Herod and Levine[22] reported fuel increases in the previous year averaging 17 percent. Average increases of 16 percent were reported in 1983, 12 percent in 1984[20] and 33 percent of producers reported increases averaging 32 percent in the 1985 survey.[21]

The other main problem, also related to the firing process, that has constrained the production of expanded aggregates, is the control of kiln emissions. A recent report,[40] describing the production of lightweight aggregate by Texas Industries Inc., of Houston, Texas, in a 3.5 by 75 m rotary kiln, notes that environmental protection measures associated with the plant would "take a million dollars to replace". Such capital expenditure is a considerable constraint on the development of new or upgraded plants.

To overcome the limitations of the rotary kiln, other process approaches and modifications have been introduced. One of the most successful is a radical modification of the rotary kiln production method. Developed by Rohrbach Technologie of West Germany, the Liapore process was introduced in 1967. The process has a heat requirement of approximately 2.8 x 10^6 J/kg,[24] while allowing production of any desired bulk density down to less than 300 kg/m^3. The kiln operates in three stages: drying and preheating; expansion; and cooling. To conserve heat, part of the cooling air is used for predrying the clay. A Canadian patent[39] was issued to Rohrbach in 1983 which included means to modify conventional rotary kilns to meet the requirements of the Liapore process.

The use of kiln internal structures to improve heat efficiency is well established. Biege and Cohen[5] found that such devices could result in fuel savings of approximately 650 x 10^3 J/kg. An extreme form of modification of a rotary kiln is the use of a trefoil. A trefoil kiln, developed by Thermal Conversion (U.K.) Ltd., of Dartford, Kent, England, has been installed at a plant in South Wales for the production of lightweight aggregate from colliery waste (shale). The kiln has a trefoil cross–section shape instead of the conventional circular section with a high temperature resistant metal lining rather than firebricks. Advantages cited include low thermal inertia (heat capacity), no heat loss through the shell, low maintenance costs, flexible operation and good mixing. It is expected to produce aggregate with density that can be controlled from 250 to 750 kg/m^3 using a foaming technique.[42]

Cohen has proposed the use of a fluid bed reactor for the production of sealed (coated) aggregate in the fine size grades required for the manufacture of concrete block.[10] Using a fine feed material, laboratory scale tests showed that a product of 830–880 kg/m^3 could be produced without the sticking and ring formation typical of producing aggregate from fines in a rotary kiln. Although it is not specified in the report, it is understood that the 'fine–feed' used was crusher fines and/or dust from a rotary kiln production unit. It is difficult to imagine how moist pelletized clay or shale could be handled in a fluid bed; no such problem would exist with a dry feed. Enquiries of the Fuller Company established that no plant using fluidized–bed technology was in operation in North America or elsewhere to their knowledge.[15]

THE MANUFACTURE OF EXPANDED BLAST–FURNACE SLAG

Blast furnace slag is the non–metallic residue from the smelting of iron ore. It is essentially a mixture of calcium–magnesium–aluminum silicates which remain after the removal of molten iron from the furnace charge of iron ore, limestone, dolomite and coke. Molten slag, which floats on top of the molten iron in the bottom of the blast furnace, is periodically tapped off and discharged to cooling pits.

Three slag products are produced as a result of three cooling methods: air cooled or hard slag, granulated slag, and expanded or foamed slag.

Air Cooled Slag

Most of the molten slag tapped from the furnace is discharged into large open pits for natural air cooling. The cooling process may be accelerated by spraying with water once initial solidification has occurred. Even so, complete cooling may take as long as a week.

Air cooled slag is the densest and strongest of the slag products. With a specific gravity of 2.0 to 2.5, it is about 20 percent lighter than normal gravel

or crushed stone. Bulk density is between 1100 and 1350 kg/m³.

Uses for air cooled slag include railroad ballast, rock wool manufacture, roofing aggregate, asphalt highway surfacing, concrete aggregate and numerous other construction aggregate applications.

Granulated Slag

Granulated slag is a glassy granular product formed when molten slag is rapidly chilled by immersion in water. The process is usually one of simply pouring the molten slag into a pit of water. Or it can be produced by the "jet process", whereby high pressure streams of water are directed against a flow of molten slag, breaking the flow into droplets which are further quenched in a water pool.

Finely ground granulated slag in the presence of moisture will set and harden as a cement. It is sometimes used as the principal ingredient in making portland cement, but more often it is ground with varying proportions of portland cement to make "portland blast furnace slag cement". Or it comprises the major part of "slag cement", sometimes with minor additions of lime and air–entraining agents. Granulated slag is also used as an aggregate in highway construction and concrete products. Along with the fine sized air cooled slag screenings, it is used to some extent as an agricultural liming material and soil conditioner.

Expanded Slag

A medium weight cellular aggregate results from the treatment of molten slag with controlled amounts of water, steam, compressed air, or a combination of these. Several methods are used, including the pouring of molten slag in open pits and various mechanical techniques.

In 1968 National Slag of Hamilton developed a method, now used widely throughout the world, for producing pelletized expanded slag.[50,12,41,25] In a patented process,[48] molten slag is first expanded by water sprays, then passed over a rapidly revolving drum containing fins which deflect the stream into droplets and propel them into a collecting area. The droplets become sealed cellular pellets during flight. Pellet size is controlled by feed rate and drum speed, eliminating the need for crushing. Bulk densities range between 560 and 1100 kg/m³; the coarser the aggregate, the lower its density. An important feature of the process is the nearly complete sealing in of the sulphurous fumes formerly released to the air.

The principal use for expanded slag is as an aggregate in lightweight concrete products such as concrete blocks and other masonry units and precast shapes. It is also used as an aggregate for on–site pouring of concrete floors and other structural members, particularly in multiple–storey buildings where less weight requires less structural steel in their construction. Because of its high content of glassy material when finely ground, pelletized slag has cementitious properties and slag cement has become the major market for these products.

LIGHTWEIGHT AGGREGATE FROM FLY ASH

Coal has been used in Europe, particularly in Britain, for the manufacture of lightweight aggregate for many years.[32] In addition, interest has been shown in the U.S.A.[33,51] recently due to social pressures to dispose of ashes usefully.

Bottom ash (known also as boiler slag) may be suitable without further processing for some applications as lightweight aggregate. Such utilization will be governed by the size gradation, chemical composition of soluble salts and the presence or absence of pyrites in the ash.

Fly ash is a potential raw material for the manufacture of lightweight aggregate. The manufacture of aggregate from fly ash involves sintering the material at 1000 to 1200°C. A prerequisite to any currently applied method of sintering is that the ash should be pelletized before firing. This is usually achieved by the use of a shallow pan pelletizer. The pelletized ash is converted to lightweight aggregate by firing in a shaft kiln, a sinter strand or a rotary kiln. The most successful process, the Lytag process, uses a travelling grate sinter machine.

Fly ash may bring to the lightweight aggregate process the following properties:

- carbon content that may contribute to the fuel demand of the sintering stage;
- chemical composition similar to the clays also used;
- the presence of glassy phases that may reduce the energy demands of sintering;
- in some ashes, reactivity with water may contribute to the formation and quality of 'green' pellets.

Major problems which may be associated with ash use in the lightweight aggregate industry are related to the uniformity of composition of ash and the presence of soluble salts.

In order to be satisfactory, the fly ash must be of uniform composition, particularly with respect to carbon content. Ideally, the source of the fly ash

should be a base–load station, where power demand is constant rather than a peak–load station where demand fluctuates. Pretreatment may be necessary to adjust composition, grain size, and to extract components such as iron.

The presence of water–soluble salts, in particular sulphates, may lead to increased efflorescence in a similar way to that forming on clay brick.

The Lytag Company of Great Britain is among the leaders in the field of fly ash aggregate manufacture, and currently operates two sinter plants in England. In 1976 Moss[29] reported that some 4.2 x 10^6 m^3 of Lytag aggregate had been used to produce a range of concretes from 1280 kg/m^3 through 1762 kg/m^3 and from 3.45 to 55.16 MPa compressive strength.

In recent years, the subject of fly ash utilization in the manufacture of lightweight aggregate has been much discussed in Canada, particularly in the light of the growing disposal problems faced by the electrical utility companies. However, although a large pilot facility was constructed in Mississauga, Ontario in the early 1970s, no commercial production has yet occurred.[7]

Covey has stated[13] that the cost of producing lightweight aggregate from fly ash is sufficiently higher than the costs of other production approaches as to render it uncompetitive. It is understood that the only commercial plant to produce a sintered fly ash product in the United States is no longer in production.[38]

USES, SPECIFICATIONS AND PROPERTIES OF EXPANDED AGGREGATES

USES

With the exception of the ultra–lightweight materials produced from vermiculite and perlite, expanded aggregates are used primarily to reduce the unit weight of construction materials and to provide thermal or sound insulation. Other uses include their application as backfill behind structures where rapid drainage and reduced dead–loads are required; as skid–resistant aggregate for asphaltic pavements; and in various horticultural products. By far the largest single application is in the manufacture of concrete block, which consumes close to 70 percent of the expanded clay and shale produced in North America.

Detailed descriptions of the use of lightweight aggregates are available from many published sources. Wilson[56] has reviewed the principal aspect of their use in both structural concrete and concrete block, and Cotsworth has discussed the use of pelletized slag in concrete masonry.[12]

SPECIFICATIONS

Specifications for the use of expanded clay, shale and slag aggregates, and for concretes prepared from them, are contained in the Canadian Standards Association (CSA) standard CAN–A23.1–M77 entitled "Concrete Materials and Methods of Concrete Construction". Both normal and lighter weight aggregates are covered. The part dealing with expanded aggregates has been largely taken from standards of the American Society for Testing and Materials (ASTM) as follows:

C 330–77: *Lightweight aggregates for structural concrete*,

C 331–77: *Lightweight aggregates for concrete masonry units*,

C 332–77: *Lightweight aggregates for insulating concrete*.

These specifications have to do with physical grading and densities of various aggregates, and with strength and thermal conductivity of resulting concretes.

PROPERTIES

Grading

As with any other aggregate used in concrete, the relative proportion of particles of different sizes (grading) of lightweight aggregates profoundly affect the properties of the finished product. In Table 7.2, the grading requirements imposed by ASTM C 330 are given for seven different grades of aggregates for use in structural concrete.

Where the aggregate is required for production of concrete masonry, different gradations apply (Table 7.3). Similarly, where the purpose is to produce insulating concrete, the gradations in Table 7.4 are required.

Density

In North America, lightweight aggregates generally have densities between 600 and 1100 kg/m^3 (40 and 60 lb/ft^3).[60] Table 7.5 shows the requirements regarding unit weight for lightweight aggregate to meet ASTM C 330–75a. Aggregates conforming to these standards will produce concrete with the weight–strength relationship shown in Table 7.6.

In Europe, where thermal insulation of concrete is considered a primary factor, the practice is to

TABLE 7.2 GRADING REQUIREMENTS FOR LIGHTWEIGHT AGGREGATES FOR STRUCTURAL CONCRETE* (56)

	Percentage (by Weight) Passing Selves Having Square Openings								
Size Designation	1 in. (25.4 mm)	3/4 in. (19.0 mm)	1/2 in. (12.5 mm)	3/8 in. (9.5 mm)	No. 4 (4.75 mm)	No. 8 (2.36 mm)	No. 16 (1.18 mm)	No. 50 (300 µm)	No. 100 (150 µm)
Fine aggregate:									
No. 4 (4.75 mm) to 0	–	–	–	100	85–100	–	40–80	10–35	5–25
Coarse aggregate:									
1 in. to 1/2 in. (25 to 12.5 mm)	95–100	–	0–10	–	–	–	–	–	–
1 in. to No. 4 (25 to 4.75 mm)	95–100	–	25–60	–	0–10	–	–	–	–
3/4 in. to No. 4 (19 to 4.75 mm)	100	90–100	–	20–60	0–10	–	–	–	–
1/2 in. to No. 4 (12.5 to 4.75 mm)	–	100	90–100	40–80	0–20	0–10	–	–	–
3/8 in. to No. 8 (9.5 to 2.36 mm)	–	–	100	80–100	5–40	0–20	–	–	–
Combined fine & coarse aggregate:									
1/2 in. (12.5 mm) to 0	–	100	95–100	–	50–80	–	–	5–20	2–15
3/8 in. (9.5 mm) to 0	–	–	100	90–100	65–90	35–90	–	10–25	5–15

*From ASTM C 330–75a

TABLE 7.3 GRADING REQUIREMENTS FOR LIGHTWEIGHT AGGREGATES FOR CONCRETE MASONRY UNITS*. (56)

	Percentage (by Weight) Passing Sieves Having Square Openings							
Size Designation	3/4 in. (19.0 mm)	1/2 in. (12.5 mm)	3/8 in. (9.5 mm)	No. 4 (4.75 mm)	No. 8 (2.36 mm)	No. 16 (1.18 mm)	No. 50 (300 µm)	No. 100 (150 µm)
Fine aggregate:								
No. 4 (4.75 mm) to 0	–	–	100	85–100	–	40–80	10–35	5–25
Coarse aggregate:								
1/2 in. to No. 4 (12.5 to 4.75 mm)	100	90–100	40–80	0–20	0–10	–	–	–
3/8 in. to No. 8 (9.5 to 2.36 mm)	–	100	80–100	5–40	0–20	–	–	–
Combined fine & coarse aggregate:								
1/2 in. (12.5 mm) to 0	100	95–100	–	50–80	–	–	5–20	2–15
3/8 in. (9.5 mm) to 0	–	100	90–100	65–90	35–65	–	10–25	5–15

*From ASTM C 331–69

TABLE 7.4 GRADING REQUIREMENTS FOR GROUP II** LIGHTWEIGHT AGGREGATES FOR INSULATING CONCRETE*. (56)

	Percentage (by Weight) Passing Sieves Having Square Opening								
Size Designation	3/4 in. (19.0 mm)	1/2 in. (12.5 mm)	3/8 in. (9.5 mm)	No. 4 (4.75 mm)	No. 8 (2.36 mm)	No. 16 (1.18 mm)	No. 30 (600 mm)	No. 50 (300 µm)	No. 100 (150 µm)
Fine aggregate:									
No. 4 (4.75 mm) to 0	–	–	100	85–100	–	40–80	–	10–35	5–25
Coarse aggregate:									
1/2 in. to No. 4 (12.5 to 4.75 mm)	100	90–100	40–80	0–20	0–10	–	–	–	–
3/8 in. to No. 8 (4.75 to 2.36 mm)	–	100	80–100	5–40	0–20	–	–	–	–
No. 4 to No. 8 (4.75 to 2.36 mm)	–	–	100	90–100	0–20	–	–	–	–
Combined fine and coarse aggregate:									
1/2 in. (12.5 mm) to 0	100	95–100	–	50–80	–	–	–	5–20	2–15
3/8 in. (9.5 mm) to 0	–	100	90–100	65–90	35–65	–	–	10–25	5–15

*From ASTM C 332–66
**Group II aggregates are those produced from expanded clay, shale or slate

produce lightweight aggregate of lower density (320 to 800 kg/m³) than in North America. This should be taken into account when consideration is given to European production methods in terms of their application in North America.

TABLE 7.5 MAXIMUM UNIT WEIGHT OF LIGHTWEIGHT AGGREGATE*.(56)

Size Designation	Dry, Loose Unit Weight lb/ft³	kg/m³
Fine aggregate	70	1120
Coarse aggregate	55	880
Combined fine and coarse aggregate	65	1040

*From ASTM C 330–75a

Thermal Properties

Concern with the thermal insulation properties of lightweight aggregate centres on the thermal properties of lightweight concrete. Wilson[60] has reported the following data relating concrete density to thermal conductivity.

Range of Concrete Density (kg/m³)	*Range of Thermal Conductivity (W/mK)*
1700 to 1900	0.68 to 0.77 (at ambient temperatures)
	0.75 to 0.95 (at 300°C)[57]
500 to 1500	0.10 to 0.35 (at ambient temperatures)[18]

The moisture content of the concrete has a major influence on thermal conductivity and must be controlled during measurements.

Properties of Expanded Slag

Depending upon the source of the slag and the process used for expansion, the properties of slag aggregates vary considerably. The density may range from 400 to 1120 kg/m³. Thermal conductivities reported by Wilson[58] are shown in Table 7.7. The thermal and structural properties of concretes made from expanded slags have been reviewed by Wilson[58] who also has reported the properties of expanded slag concrete masonry units shown in Table 7.8.

THE LIGHTWEIGHT AGGREGATE INDUSTRY IN CANADA

EXPANDED CLAY AND SHALE

The first manufactured lightweight aggregate in Canada was produced at Cooksville (now Mississauga), Ontario in 1927. Termed Haydite, it was made at the same site by Domtar Inc. from 1928 until 1980 when the plant closed. From 1927 until 1953, when a second plant was built in Calgary, Alberta, Canadian production was limited to this one source. By the end of 1954, four plants were in operation with a total annual production of 130,000 m³. Production capacity continued to increase to 1960, with 10 plants producing 279,000 m³. Production increased to 390,000 m³ from 9 plants by 1965. Until 1977, production grew and finally fluctuated between 550,000 and 740,000 m³.[56,60] In 1977 it was at 576,600 m³, and has since continued to decline (see Table 7.10). At the time of writing, the companies listed in Table 7.9 are reportedly in production.

Another plant owned by Avon Aggregates Ltd., at Minto, New Brunswick, while still in place, has not produced aggregate since 1984, sales being limited to material in stock.[61] From 1978 to date, plants at Mississauga, Ontario (Domtar Inc.), Namao, Alberta (Aerlite Products Ltd.) and Minto, New Brunswick have ceased production. As is discussed elsewhere in this chapter, the decline in production and consumption of expanded clay and shale aggregates is not isolated to Canada. The industry in the United States has also shown a steady reduction over a similar time period.

EXPANDED SLAG

Until about 1920, when it started to be crushed and screened for railway ballast and road surfacing, blast furnace slag was treated as a waste product in Canada. The first production of expanded slag was in Sydney, Nova Scotia, from 1947 to 1968. It has been produced in Hamilton, Ontario, since 1954, where National Slag Limited continues to be the only Canadian producer of expanded slag for use as aggregate.

PRODUCTION OF EXPANDED AGGREGATE IN ONTARIO

There have been three attempts to establish lightweight aggregate production in Ontario: the Haydite plant of Domtar Inc. at Mississauga; the expanded (pelletized) slag production of National Slag Ltd. in Hamilton; and an attempt to produce sintered fly ash aggregate by Enercon Ltd. at the Ontario Hydro, Lakeview power station. Of these, only the pelletized slag operation is in production today.

Domtar Inc., Haydite

An expanded shale aggregate, known as Haydite after its inventor S.J. Hayde, was made by Domtar

TABLE 7.6 RELATIONSHIP BETWEEN WEIGHT AND STRENGTH OF STRUCTURAL CONCRETE*. (56)

Average Unit Weight, max.		Average 28-day Splitting Tensile Strength, min.		Average 28-day Compressive Strength, min.	
lb/ft³	kg/m³	psi	MPa	psi	MPa
115	2	290	2	4000 or more	23 or more
110	2	290	2	3000	21
105	2	290	2	2500	17

*From ASTM C 330–75a

TABLE 7.7 THERMAL CONDUCTIVITY OF EXPANDED SLAG. (56)

Coarse Expanded Slag 1/2 in. to No. 4: 40 lb/ft³ (12.5 to 4.8 mm : 640 kg/m³) Thermal Conductivity				Blended Expanded Slag 1/2 in. to dust : 60 lb/ft³ (12.5 mm to dust : 960 kg/m³) Thermal Conductivity			
Mean Temp. °C	Mean Temp. °F	Btu in./hr ft.² deg F	W/m°C	Mean Temp. °C	Mean Temp. °F	Btu in./hr ft² deg F	W/m°C
199.2	92.9	0.77	0.11	217.9	103.3	1.16	0.17
213.6	100.9	0.78	0.11	233.6	112.0	1.25	0.18
248.7	120.4	0.97	0.14	250.5	121.4	1.32	0.19
				255.2	124.0	1.42	0.20

TABLE 7.8 PROPERTIES OF EXPANDED SLAG CONCRETE MASONRY UNITS*. (56)

Sound Absorption		**Noise Reduction Coefficient****
4 in. (102 mm) hollow block		
fine texture		0.60
coarse texture		0.50
8 in. (203 mm) solid block		0.75
Sound Transmission		**Decibel Loss**
8 in. (203 mm) hollow block unplastered		45.0
1 in. (25 mm) plaster		52.6
Thermal Insulation	**Btu in./hr. ft² deg F**	**W/mK**
90 lb/ft³ (1440 kg/m³) concrete	2.60	0.37
Fire Resistance		**Rating**
4.7 in. (118.4 mm) thickness		4 hour
Modulus of Elasticity	**psi**	**MPa**
Block of average compressive strength	1.6×10^6	1.1×10^4
Compressive Strength		Meets ASTM specification (Designation C 331-69)
Drying Shrinkage		Low pressure cured: pre-dried, have low residual shrinkage. High pressure cured: normally less total shrinkage than other lightweight masonry.

* Information supplied by National Slag Ltd.
** The absorbed fraction of the sound energy incident on a material.

TABLE 7.9 EXPANDED AGGREGATE PLANTS IN CANADA.(45,61)

Name	Location	Raw Material
Apex Aggregates Ltd.	Saskatoon, Sask.	Clay
Cindercrete Products Ltd.	Regina, Sask.	Clay
Consolidated Concrete Ltd.	Calgary, Alta.	Shale
Consolidated Concrete Ltd.	Edmonton, Alta.	Clay
Genstar, Edcon Block Div.	Edmonton, Alta.	Clay
Kildonan Concrete Products Ltd.	Winnipeg, Man.	Clay
National Slag Ltd.	Hamilton, Ont.	Slag

Inc. at Mississauga from 1928 to 1980. A volume expansion of about 100 percent resulted in an aggregate weighing about 650 kg/m³, 40 percent the weight of normal sand, gravel and crushed stone.

The plant and process have been described by Wilson.[59] Georgian Bay Shale was obtained from an adjoining quarry, which also served the needs of Domtar's brick plant at the same site. Haydite was produced in rotary kilns, and the resulting clinker was crushed and screened to various sizes. Greatest demand was for Haydite sand, primarily for use in concrete block where its uniformity of colour and texture resulted in a premium product. The ready-mix concrete market was next in terms of volume, followed by a variety of refractory uses.

An increasing chloride content with depth in the Domtar shale quarry resulted in the lower levels being worked exclusively for Haydite. Chlorides produce an undesirable scum or efflorescence on brick surfaces. While the quarry had been deepened to nearly 30 m, shale from the lower half was only used for making Haydite.

In 1965, a fourth rotary kiln was installed to make coated aggregate from pelletized shale. By 1975 the cost of fuel (natural gas) had increased to about 50 percent of the overall cost of the aggregate, and the three older kilns were shut down. The fourth kiln continued to produce at the rate of 150 m³/day (53,000 m³ annually) until 1980.

Increasing fuel costs and environmental pressures against the shale dust in stack emissions forced closure of the plant in December 1980.

National Slag Limited

National Slag Limited of Windermere Road in Hamilton purchases slag from the blast furnaces of Stelco and Dofasco. It is trucked from the iron works, either as air-cooled slag or expanded slag. Uses for the slag include numerous applications as construction aggregate, railway ballast, mineral wool manufacture and slag cement.[14]

The air cooled variety is the standard waste product of the furnaces and is about 20 percent lighter than stone. It has a specific gravity of 2.2 (bulk density of 1200 kg/m³). From stockpile the slag is reclaimed by dragline and loaded to a hopper feeding a picking belt for the removal of iron. A cone crusher with an 8 cm discharge is followed by screens which provide 10 product sizes. Three magnetic pulleys handle the removal of iron from various screened fractions. A large slag market is in the manufacture of mineral wool, for which 5 cm to 8 cm lump is preferred. Much of the 3 cm fraction is used in road building. Crushed slag has a very desirable particle shape — a minimum of slabby or splintery particles — and hence the 1 cm size is preferred to other materials for industrial roofing (flat roofs), and finer sizes are used also as granules in asphalt shingles.

Expanded slag was formerly handled in a separate but similar crushing circuit. It was also received by truck from the steel plants where it was made by adding water to the molten slag in facilities set up by National Slag. The explosive evolution of steam resulted in increased porosity. Bulk densities of the crushed products ranged between 670 and 880 kg/m³, lighter densities favouring the coarser products.

National Slag pioneered the development of a process for producing coated expanded aggregate, and in 1968 began its commercial production. The technique is now extensively used worldwide. The slag stream is expanded by water sprays, then deflected and propelled by the fins of a revolving drum. Cellular slag droplets are chilled and sealed during their passage through the air to a collecting area. The process benefits by producing a superior product and by sealing in much of the sulphurous gases formerly released to the atmosphere. Expanded slag granules are produced in controlled size ranges of 1 to 10 mm, with bulk densities of 840 to 1070 kg/m³.

Enercon Inc.

In the early 1970s, Enercon Ltd. of Toronto, developed and installed an ash beneficiation plant at the Lakeview Generating Station.[7] The plant was developed to co-produce lightweight aggregate and pozzolans with concurrent separation of other valuable fractions from the ash. A large pilot facility was constructed in Mississauga, Ontario, but no significant commercial production occurred, and the plant has been dismantled.[4]

DECLINE OF THE EXPANDED AGGREGATE INDUSTRY IN NORTH AMERICA

In the light of the previously noted reductions in production of expanded clay and shale aggregates, both in Canada and the U.S., and the closure of the only plant in Ontario, it is useful to examine the manner of this decline and its probable causes.

A number of factors appear to have affected the industry in North America at about the same time. Firstly, starting in 1973, crude oil and hence other energy costs rose dramatically (Figure 7.2). Secondly, throughout the 1960s and 1970s, the North American public became aware of the hazards of industrial pollution, and considerable pressure was exerted through legislation and regulation to reduce all industrial emissions. Thirdly, the North American economy went through a recession second only to that of the 1930s. This resulted in a substantial slowing of the rate of spending on new construction and severely limited markets for construction products. Finally, new products entered the construction marketplace, such as pelletized slag and replacements for concrete block.

Cost of Fuel

Mention has already been made of the fuel cost increases faced by U.S. producers over the period 1982 to 1985. These were imposed after the major increases of the 1970s. There is no means to segregate fuel costs as a principal factor in the decline of the U.S. industry, because fuel costs were largely a cause of other recessionary problems. However, the potential influence of fuel costs on production costs for expanded aggregate is significant, and a chronological correlation is clearly seen in the U.S. data shown in Figure 7.2, with severe production cuts following immediately upon the first of the rapid oil cost increases. Of interest is the observation that Canadian production was unaffected by either of the major oil price increases. The decline of the Canadian industry occurred after 1981 when oil prices were much less volatile.

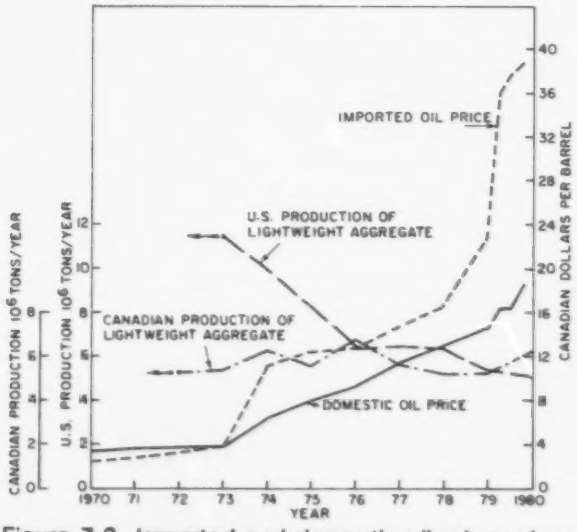
IMPORTED OIL PRICE
U.S. PRODUCTION OF LIGHTWEIGHT AGGREGATE
CANADIAN PRODUCTION OF LIGHTWEIGHT AGGREGATE
DOMESTIC OIL PRICE
CANADIAN PRODUCTION 10⁶ TONS/YEAR
U.S. PRODUCTION 10⁶ TONS/YEAR
CANADIAN DOLLARS PER BARREL
YEAR
1970 71 72 73 74 75 76 77 78 79 1980

Figure 7.2 Imported and domestic oil prices since 1970, in current Canadian dollars per barrel compared with lightweight aggregate production.[11]

Expanded Aggregate Production and Construction Activity, 1975 to 1984

Canada

In Table 7.10 the annual production data for lightweight aggregate from expanded clay and shale are reported for the years 1975 to 1984. For comparison, annual construction activity in $(current) and $(1975) is reported for the same period.

Considering the data on production from 1975 to 1980, Canadian production was relatively constant, fluctuating from lows of 520,000 m^3 to highs of 660,000 m^3. In 1981 a decline in production started, in step with a sharp fall in the average value in both $(current) and $(1975) of the product. From 1981 to 1984 production fell by 71 percent from 520,000 m^3. Concurrently, prices rose in $(current) but were eroded by inflation and remained largely unchanged from their 1979, previous peak value, in $(1975).

During the same period, 1975 to 1984, the total value of Canadian construction, considered in $(1975), rose to a peak in 1981 and then declined slightly (by 18 percent) to 1984. The magnitude of the cycle in construction was far less than that for expanded aggregate. Included in Table 7.10 are two computed "Utilization Factors" relating the annual quantity of aggregate produced to the value of Canadian construction for both $(current) and $(1975).

Clearly, it is apparent that with or without the influence of inflation on the costs of construction, lightweight aggregate steadily lost its place as a construction material in Canada from 1976 on.

United States

Table 7.11 shows similar data (average values are not available for expanded aggregate from U.S. sources) for U.S. production of expanded clay, shale and slate. While less severe, the pattern is similar to that for Canadian production, with reduction in quantity produced being reported for 9 out of 11 consecutive years.

TABLE 7.10 PRODUCTION OF LIGHTWEIGHT AGGREGATE AND TOTAL VALUE OF CONSTRUCTION IN CANADA, 1975 TO 1984.

	Production					$(millions)		Utilization Factor	
		Change	Value	Avg. Price ($/m³)		Construction Value		m³/$(million)	
Year	m³	%	$(000)	$(current)	$(1975)	$(current)	$(1975)	$(current)	$(1975)
1975	566,254	–	5,422	9.58	9.58	28,376	28,376	20.0	20.0
1976	661,908	16.89	7,530	11.38	10.39	33,131	30,253	20.0	21.9
1977	576,637	-12.88	6,920	12.00	10.24	35,803	30,499	16.1	18.9
1978	520,752	-9.69	6,892	13.23	10.60	38,190	30,316	13.8	17.2
1979	521,718	0.19	8,486	16.27	11.81	43,023	30,776	12.3	17.0
1980	624,069	19.62	10,261	16.44	10.75	48,327	31,604	12.9	19.7
1981	519,809	-16.71	7,091	13.64	8.10	56,884	33,787	9.1	15.4
1982	260,247	-49.93	5,832	22.41	11.96	56,065	29,932	4.6	8.7
1983	204,284	-21.50	5,050	24.72	12.47	55,948	28,222	3.7	7.2
1984	149,524	-26.81	3,560	23.81	11.69	56,130	27,557	2.7	5.4

Sources:
(a) Data on the production of lightweight aggregate were taken from relevant issues of "Canadian Minerals Yearbook" (44)
(b) Deflator for $(Canadian) based upon 1985 = 100 from reference(46)
(c) Value of construction from reference(43)

TABLE 7.11 PRODUCTION OF LIGHTWEIGHT AGGREGATE AND TOTAL VALUE OF CONSTRUCTION IN UNITED STATES, 1973 TO 1984.

	Production						Utilization Factor	
	Short Tons				Construction Value		m³/(million)	
Year	(x1000)	yd³*	m³*	% Change	$US(billion)	$(1977)	$(current)	$(1977)
1973	11,658	13,285,470	10,157,471	–	–	–	–	–
1974	10,031	11,431,339	8,739,886	-13.96	–	–	–	–
1975	8,139	9,275,214	7,091,410	-18.86	136	152	52.1	46.7
1976	6,181	7,043,875	5,385,429	-24.06	151	163	35.7	33.0
1977	6,258	7,131,624	5,452,518	1.25	174	174	31.4	31.3
1978	6,190	7,054,131	5,393,270	-1.09	206	182	26.2	29.6
1979	5,681	6,474,074	4,949,785	-8.22	230	179	21.5	27.7
1980	5,438	6,197,151	4,738,062	-4.28	231	161	20.5	29.4
1981	4,917	5,603,419	4,284,121	-9.58	238	158	18.0	27.2
1982	4,034	4,597,151	3,514,774	-17.96	230	151	15.3	23.3
1983	4,396	5,009,687	3,830,180	8.97	–	167	–	22.9
1984	4,378	4,989,174	3,814,497	-0.41	–	182	–	21.0

* Calculated values based upon unit weight of 65 lb/ft³ for lightweight aggregate.
Sources:
(a) Production data from U.S. Bureau of Mines(2)
(b) Construction value from U.S. Bureau of Census(47)

In annual reviews of the status of lightweight aggregate production, as each decline has been reported, it has been attributed to slowing of construction activity.[1] However, analysis of the data in Table 7.11 shows that although a major cycle has occurred in construction activity in the United States (peaking in 1978 and falling to a minimum in 1982, when considered in $(1977)), no corresponding cycle has appeared in sales of expanded aggregate. As the utilization factors show, in spite of optimistic forecasts in the trade literature, the industry has shown a steady reduction in its position in the construction marketplace.

Expanded Aggregate Production and the Concrete Products Manufacturing Industry

Canada

In Table 7.12 the distribution of consumption of expanded clay and shale aggregates by end use is presented. As is seen, some 75 to 80 percent of the aggregate produced is used in concrete block. A similar distribution of use is reported for the United States (see below). The data in Table 7.12 are somewhat misleading in that a percentage of declining total quantity of material is reported (see Table 7.10). A more realistic appreciation can be formed

TABLE 7.12 CANADIAN CONSUMPTION OF EXPANDED CLAY AND SHALE PERCENTAGE BY END USE, 1979 to 1984. (44)

	Percent				
Product Type	1979	1980	1981	1982	1983
Concrete block	74.7	79.2	76.7	78.7	80.6
Precast concrete	6.4	4.3	6.5	11.5	7.8
Ready-mixed concrete	13.7	13.3	14.6	4.3	6.5
Miscellaneous	5.2	3.2	2.2	5.5	5.1

TABLE 7.13 VALUE OF CANADIAN MANUFACTURED CONCRETE PRODUCTS, 1979 TO 1983.

Product Type	1979	1980	1981	1982	1983
	Value shipped, thousand $(current)				
Concrete block (SIC 354)	14,795	14,396	15,988	11,312	8,864
Precast concrete (SIC 3542)	129,271	144,870	228,522	263,431	201,632
Ready-mixed concrete (SIC 3551)	687,898	736,484	905,471	843,469	864,023
	Value shipped, thousand $(1975)				
Concrete block (SIC 354)	10,746	9,414	9,496	6,039	4,471
Precast concrete (SIC 3542)	93,894	94,740	135,733	140,642	101,710
Ready-mixed concrete (SIC 3551)	499,645	481,634	537,812	450,315	435,844

Sources: Statistics Canada
CAT. 44-219
CAT. 44-211
CAT. 44-205

by consideration of the value of product shipped by end use, presented in Table 7.13 in current and (1975) dollars.

In Table 7.14 an analysis is given in terms of the distribution of quantity shipped, value in $(current) and the proportion of the value of the end use product that is represented by the value of the aggregate.

From these data, it is reasonable to note that, Canada wide, from 1979 to 1983 the following general factors are apparent.

1. The concrete block market fell from $14.8 million to $8.9 million. In terms of constant dollars (1975), this decline was from $10.7 million to $4.5 million. With a corresponding fall in unit shipments from 25.5 million to 8.9 million.
2. With the exception of uneven performance in 1980–1981, the value of lightweight aggregate, as a proportion of the value of shipped concrete block, remained relatively unchanged at 43 to 46 percent.
3. During the same period, both precast concrete and ready–mix concrete shipments maintained a relatively constant value (in 1975 dollars). However, the share of the value allocated to lightweight aggregate in both of these products fell from 0.42 to 0.20 percent in precast, and from 0.17 to 0.04 percent in ready–mixed concrete.

Thus, although the proportion of expanded aggregate sold to block increased, consumption declined with the declining market for block. At the same time, expanded aggregate failed to maintain its small position as a material for other construction products.

It must be concluded that the decline in use of concrete block (with possibly some competition from slag) was the major influence on the decline of the Canadian expanded aggregate industry. This was

TABLE 7.14 ANALYSIS OF CANADIAN CONSUMPTION OF EXPANDED CLAY AND SHALE IN CONCRETE PRODUCTS, 1979 TO 1983.

Product Type	1979	1980	1981	1982	1983
			Calculated consumption (m^3/year)		
Concrete block	389,723	494,263	398,694	204,814	164,652
Precast concrete	33,390	26,835	33,788	29,928	15,934
Ready-mixed concrete	71,475	83,001	75,892	11,191	13,279
			Calculated Value ($(current)/year)		
Concrete block	6,339,042	8,126,712	5,438,797	4,589,784	4,070,300
Precast concrete	543,104	441,223	460,915	670,680	393,900
Ready-mixed concrete	1,162,582	1,364,713	1,035,286	250,776	328,250
			Value of aggregate as percent of value of finished product		
Concrete block	42.85	56.5	34.0	40.6	45.9
Precast concrete	0.42	0.25	0.20	0.25	0.20
Ready-mixed concrete	0.17	0.19	0.11	0.03	0.04

TABLE 7.15 U.S. CONSUMPTION OF EXPANDED CLAY AND SHALE BY END USE, 1979 TO 1984. (1)

Product Type	1979	1980	1981	1982	1983	1984
			Short tons			
Concrete block	3,804,138	3,554,894	2,983,586	2,152,047	2,480,786	2,671,210
Structural concrete	1,261,981	1,357,060	1,550,074	1,259,189	1,322,067	1,194,245
Highway surfacing	470,894	346,107	230,856	238,688	288,276	447,774
Other	no data	179,568	129,246	384,403	304,616	64,709
Total	5,537,013	5,437,629	4,893,762	4,034,327	4,395,445	4,377,938
			Percentage distribution			
Concrete block	68.7	65.4	61.0	53.34	56.4	61.0
Structural concrete	22.8	24.9	31.7	31.2	30.1	27.3
Highway surfacing	8.5	6.3	4.7	5.9	6.5	10.2
Other	-	3.3	2.6	9.5	6.9	1.5

not compensated for by an increase in utilization in other products.

United States

In the United States, although data are reported[1] differently (Table 7.15), the general pattern of end use is similar, with concrete block being the major consumer of expanded aggregate. In comparison with Canada, the producers of expanded aggregate depend less on concrete block (53 to 69 percent) and more on concrete for structural purposes (23 to 32 percent) for their markets. As in Canada, the demand from the concrete block industry has fallen somewhat, but less drastically. Some signs of recovery are apparent in 1983–1984.

H. C. Robinson (Managing Director, Expanded Clay, Shale and Slate Institute) has been quoted[37] as noting that the expanded aggregate industry is "making headway in recapturing the wall and divider wall market from the manufacturers of steel stud walls and the sheet rock people".

CONCLUDING REMARKS

Over the past 30 years, the production of expanded aggregate from clay and shale in Canada has passed through one complete cycle of growth and decline,

from its 1954 production level of 130,000 m^3 to a peak of 625,000 m^3 by 1984, with little evidence of immediate recovery in the near term.

In 1976 the Editor of Industrial Minerals, R.F.S. Fleming,[17] addressed the question — "Have lightweight aggregates a promising future and, if so, which ones?" — in the following way.

> "It is generally considered that they have a promising future all right but it is so far away that the best way to lose money is to go into lightweight aggregates in the present. This chronologic proviso alludes to the high and rising cost of heat-processing that many of them require, to produce in many cases an aggregate with few advantages and indeed many disadvantages as compared with a dense aggregate like sand and gravel, which needs only to be dug up, washed and graded, and which makes a stronger concrete, requiring less reinforcing. The Verney Committee, whose report on the future of U.K. aggregates in general was published last June (1976), was in fact somewhat sceptical about the future prospects for lightweight aggregates.
>
> "All this suggests that, to secure a growing market, a lightweight aggregate has to offer something more than lightness in weight, as well as be competitive in initial cost. If, for instance, it can offer continuing savings over a long term, such as savings in energy for heating a building through exceptionally good insulation properties, then it should be assured of a secure future."

Clearly, the promise has not been fulfilled in Canada or in the United States. If markets are to be developed in Ontario for lightweight aggregate, a number of factors will have to be met:

- uses must be found, on a substantial scale, in products that have displaced concrete block from the construction industry;
- a broad range of uses must be sought to prevent dependency upon one primary market segment;
- low energy consumption production methods from low-cost raw materials will have to be developed;
- use in highway pavement should be investigated and exploited if appropriate.

All of these require substantial expenditure on research, development and capital plant. Given that there is now no producer of lightweight aggregate from clay or shale in Ontario and that competition from expanded slag is likely to remain strong, it seems unlikely that investment capital will move into this activity in the short term.

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Part III — Tile, Porcelain, Whitewares and Refractories

Chapter 8 — Floor and Wall Tiles

INTRODUCTION

Ceramic floor and wall tiles traditionally have been made from mixtures of ball clay, sand, fluxes and colours, and in Europe these are still commonly used. In North America, wollastonite, pyrophyllite, talc and nepheline syenite are also important ingredients. The finely-ground mixtures are shaped by hydraulic pressing or extrusion, and may be glazed, unglazed or engobed in single or multiple firing cyles. Tiles are sold individually or in mosaics adhering to a rayon mesh backing. They are used both indoors and outdoors as the finishing material for walls, floors, swimming pools, kitchens and bathrooms.

World production is in excess of 700,000,000 m^2, of which Italy accounts for more than one-third. The U.S.A. is recognized as a major growth area for floor and wall tile use. In recent years, Canada has imported more than 90 percent of its consumption.

Windsor Ceramic Tile Canada Limited, which commenced production at Windsor, Ontario, in 1985, is an all-new, modern and highly-automated facility, and the major producer in Canada. Great Lakes Ceramics, leased the Thunderbrick plant at Thunder Bay in 1985, and plans to produce split tile for floor applications. D. A. White & Company Limited of Kingston, the former Frontenac Floor and Wall Tile Company, was closed in 1982. The plant has since been bought by Pilkington Ceramic Tile and re-opened as Clifton Ceramic Tile.

PRODUCTS AND SPECIFICATIONS

Ceramic floor and wall tiles are building materials specifically designed for use as floor and wall coverings, both interior and exterior. They may be glazed, unglazed or engobes. Glazes are impervious glassy coatings; engobes are matte, clay-based coatings which may be porous. In application, they are fixed in place by adhesives, and the joints are filled by coloured cementitious grouts. Smaller tiles may be sold as mosaics, pre-assembled with a rayon mesh backing for easier application.

There are three principal tile-forming processes: extrusion, pressing and casting. Extruded tiles are formed in a plastic state, either as individuals or two attached for later splitting. Dry pressing usually employs hydraulic presses producing multiple numbers of tiles with each cycle. Casting uses moulds and clay slips. In West Germany, Handle and Lingl have jointly developed equipment to produce thin wall tile by an electrophoresis technique.[2] North American practice recognizes the following tile types.

Ceramic mosaic tiles are formed either by pressing or extrusion. They are usually 0.6 to 1.0 cm thick (1/4 to 3/8 inches), and have an area less than 39 cm^2 (6 square inches). They may be of porcelain or natural clay composition.

Decorative thin wall tiles are thin-bodied glazed tiles that are usually non-vitreous, suitable for interior decorative residential wall use where strength is not required.

Paver tiles are glazed or unglazed porcelain or natural clay tiles formed by dry-pressing and being 39 cm^2 (6 square inches) or more in size.

Porcelain tiles are ceramic mosaic or paver tiles that are dense, impervious, fine grained and smooth with sharply formed edges, generally made by dry-pressing.

Quarry tiles are glazed or unglazed tiles 39 cm^2 (6 square inches) or more in size, made by extrusion of natural clay or shale.

Wall tiles are glazed tiles suitable for interior use; they are usually non-vitreous and are not expected to withstand excessive impact or be subjected to freezing and thawing.

Standards for ceramic floor and wall tiles are established in the U.S.A. by the American Society for Testing and Materials (ASTM). Properties measured are listed in Table 8.1. European standards are even more demanding, with established specifications for wear resistance, linear thermal expansion, chemical resistance and frost resistance in addition to those covered by ASTM.[4] European practice classifies tiles according to water absorption as given in Table 8.2.

TECHNOLOGY

The three principle manufacturing techniques for ceramic floor and wall tile are extrusion, pressing and casting. These are separately discussed in the following notes, largely taken from "Wall and Floor Tiles"[4].

TABLE 8.1 PROPERTIES SPECIFIED BY ASTM FOR CERAMIC FLOOR AND WALL TILES.(4)

	Glazed Wall Tile	Ceramic Mosaic Tile	Quarry Tile	Paver Tile
Non-destructive tests:				
Thickness	x	x	x	x
Facial dimension	x	x	x	x
Spacers	x			
Warpage	x	x	x	x
Wedging	x	x	x	x
Colour uniformity	x			
Electrical properties		x		
Destructive tests:				
Water absorption	x	x	x	x
Crazing	x	x	x	x
Thermal shock	x	x	x	x
Bond strength	x	x	x	x
Breaking strength	x	x	x	x
Abrasive hardness (glazed tile only)		x	x	x

EXTRUSION

Split Tiles

Split tiles are extruded as double tiles, weakly joined back to back, and split into individuals after firing. Clays of stoneware quality are adequate raw materials, and Ontario's brick shales might be suitable, but the Thunderbrick plant failed at least in part due to poor quality clay and shale in the Thunder Bay area. Great Lakes Ceramics was re-opening the Thunderbrick plant in 1985, with plans to use a cone 9 or 10 stoneware clay from Rockglen in southern Saskatchewan for the exclusive production of split floor tiles. Feldspar or nepheline syenite may be added to lower the firing temperature, and sand may be included to reduce plasticity.

Vacuum extrusion using suitable dies (Figure 8.1) in conventional brick and tile extruders (Photo 8.1) is followed by cutting machines designed not to deform the tiles or leave ragged or ridged edges. Tunnel dryers are considered most fuel efficient. Dried tiles are automatically stacked on edge for passage through one or more glazing units, followed by further drying. The main glazes in use are zircon specified feldspar glazes, but for more rustic finishes, glazes based on cheaper raw materials such as basalt, phonolite or pumice are used.

After glazing and further drying, the tiles are automatically transferred and stacked on kiln cars. Tunnel kilns fired near the top are preferred; energy consumption with overhead firing is 2700 to 3000 kJ per kilogram of tiles. Automatic or manual unloading is followed by machine splitting and manual sorting.

German standard DIN 19166 defines split tiles as high strength, weather and corrosion resistant components which are divided into two groups according to absorption: for grey-white tiles, mean water absorption may not exceed 3 percent; for coloured tiles, 6 percent. Fluctuations in length and

TABLE 8.2 EUROPEAN TILE CLASSIFICATION.

Classification	Water Absorption (%)
Group I	less than 3
Group II a	3 to 6
Group II b	6 to 10
Group III	More than 10

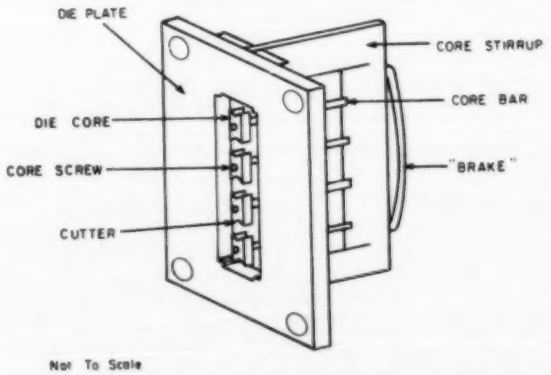

Figure 8.1 Die design for split tile production.

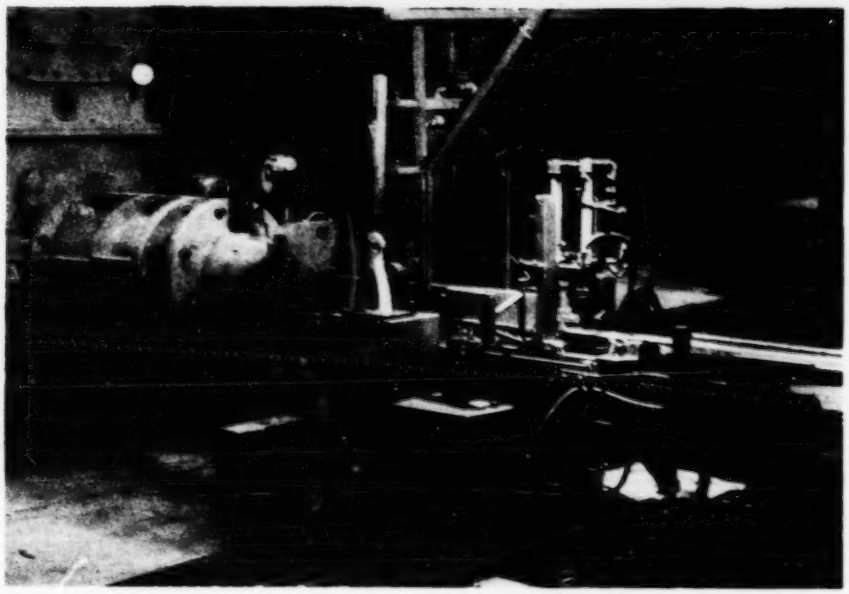

Photo 8.1 Split tile extrusion line.

breadth may not exceed ±10 percent. Specifications also deal with straightness of edge, corner angles and evenness of surface. The tile face must be uniform and free of crazing and blisters. Bending strength must be at least 20 MPa. Scratch resistance, thermal expansion, thermal shock resistance, colour and light fastness also have designated limits. Frost and acid resistance is essential.

Individually Extruded Tiles

Both quarry and mosaic tiles can be individually made by cutting an extruded clay stream, followed by glazing, pressing and punching. Coloured quarry tiles can be made from iron–rich illite shales, such as Ontario's brick shales, using conventional preparation and vacuum extrusion. Usually, a dry glaze is sifted from revolving screens onto the cut plastic segments and is pressed into the clay surface in such a way as to produce smooth or rough surfaces. Larger tiles can be produced by rolling out an extruded segment. Firing can be effectively done in a single layer using roller hearth kilns.

Individually extruded tiles can be used on wall, floor and facade coverings. European standards specify frost resistance in addition to water absorption, but ASTM Specification C 373 only specifies water absorption.

DRY PRESSING

Dry finely ground clay bodies can be pressed in tile moulds under high pressure and subsequently glazed if desired. Glazing, however, is normal, and multiple firing is common. Single firing is generally used for stoneware and cottoforte in Europe, and for mosaic, paver, quarry and glazed wall tiles in the U.S.A. But for thin earthenware, majolica and cottoforte, two or three firings may be used to facilitate mechanical decoration.

In Europe, light stoneware is based almost exclusively on ball clays plus feldspar, quartz and rejects. In the U.S.A., coloured stoneware sometimes uses shale with fireclay and chamotte (calcined plastic kaolinitic clay). The new Windsor Ceramics plant in southwestern Ontario uses an Ohio fireclay with or without local surface clay and nepheline syenite.

Italian coloured cottoforte and similar Spanish tiles are sometimes made from a single local clay plus some calcined material. A typical cottoforte clay may be highly calcareous, like many Ontario surface clays, and have the properties and firing characteristics shown in Table 8.3.

In the U.S.A., pyrophyllite, talc and wollastonite are the principal raw materials for grey–white tile bodies. They permit energy–efficient, single fast firing of wall tiles in sizes such as 11.4 cm x 11.4 cm (4–1/2 x 4–1/2 inches), 15.2 cm x 15.2 cm (6 x 6 inches) and 20.3 cm x 20.3 cm (8 x 8 inches).

TABLE 8.3 TYPICAL COLOURED COTTOFORTE CLAY.(4)

Chemical Composition (%):

SiO_2	49.37	K_2O	2.35
Al_2O_3	18.31	Na_2O	0.97
Fe_2O_3	4.59	SO_3	0.03
TiO_2	0.54	$CrCO_3$	0.14
CaO	8.60	LOI	11.97
MgO	3.13		

Fired properties:

Firing Temperature (°C)	Linear Firing Shrinkage (%)	Fired Weight Loss (%)	Water Absorption (%)	Fired Colour
980	1.0	11.5	15.4	Yellow
1000	0.8	11.2	14.8	Pink
1020	0.8	11.0	15.0	Pink
1040	0.9	11.4	15.6	Pink

Pyrophyllite, ($Al_2O_3.4SiO_2.H_2O$) when used as a partial substitute for flint and feldspar in wall tile bodies, contributes to a reduction in thermal expansion, moisture expansion and contraction.

Talc ($3MgO.4SiO_2.H_2O$) may constitute as much as 50 percent of feldspar–free bodies, or 10 percent of feldspar–bearing bodies. It permits rapid firing of the tile without crazing of the glaze.

Wollastonite ($CaO.SiO_2$) may constitute as much as 50 percent of porous wall tile bodies, contributing reduced shrinkage and good thermal shock resistance.

Talc, wollastonite and pyrophyllite are little used in Europe because they are not readily available. Instead, wall tile bodies contain as many as fifteen different ingredients, including white firing carbonaceous ball clays low in iron, raw and refined kaolin, chalk and feldspar. In contrast to the coloured Italian and Spanish bodies, this body fires to a white to cream colour.

Some typical tile body formulations are given in Table 8.4.

Preparation of floor and wall tile batches can be either wet or dry (Figure 8.2). In the wet method, as many of the ingredients as possible are prepared in a blunger, and the resulting slip is dried to 4–6 percent moisture in a spray dryer. Dry preparation lends itself to simple batch compositions of only a few ingredients. Hard materials such as broken tiles, bricks and other chamottes are ground separately in traditional crushing and grinding circuits before mixing with clays. Prepared batch materials are stored in silos before use, partly to ensure even distribution of moisture content.

Hydraulic tile presses have mostly replaced the friction screw press. Pressing forces can range between 1000 kN and 10,000 kN, larger tiles requiring greater pressures than smaller tiles. Pressing agents are sometimes added to the slip before spray drying to improve the bulk density and compressive strength of the tile.

In the single firing process, roller bascule dryers are preferred before firing. Stack–loaded tunnel dryers, or vertical dryers for individual tiles, are used in multiple firing processes. For cottoforte and similar products, preliminary drying may be necessary ahead of tunnel dryers, but not when fast dryers are used. Heat consumption of at least 8 MJ/kg of evaporated water is typical of fast dryers; 3 MJ/kg for traditional tunnel dryers, and 4 to 5.3 MJ/kg for microwave dryers.

Open flame tunnel kilns are traditionally used for biscuit firing. White earthenware is fired at 1000°C to 1230°C; cottoforte, cotto and majolica at about 1000°C. Automatic stacking machines are used for loading kiln cars, and semi–automatic grabs are used for unloading. Sorting for cracked and chipped tiles is not usually cost effective unless rejects exceed 5 percent.

Biscuit ware may be packed for shipment to other finishing plants, or conveyed to the glazing unit. Raw glazes are used at about 1200°C, about the same temperature used for single fired stoneware. Frit glazes require strong fluxes to lower their firing temperature, and this may mean reduced chemical resistance in the finished glaze. Fillers such as corundum, calcined alumina and zircon

TABLE 8.4 TYPICAL TILE BODY FORMULATIONS. (3)

Tile Type				
Body	**Porosity**	**Body Colour**	**Body Formulation (%)***	
Conventional European	Porous	White	China clay	25
			Ball clay	25
			Quartz	35
			Feldspar	10
Lime body	Porous	White	China clay	10
			Ball clay	30
			Quartz	45
			Feldspar	5
			Lime	10
Talc	Porous	White	Talc	67
			Ball clay	28
			Wollastonite	5
High wollastonite	Porous	White	Wollastonite	55
			China clay	30
			Quartz	15
Talc-pyrophillite	Porous	White	Talc	35
			Pyrophyllite	16
			Ball clay	24
			Quartz	17
			Lime	8
Quarry	Porous	Red-brown	Common clay	80–90
			Feldspar	10–20
Vitrified clay body	Vitrified	Various	Ball clay	70
			Feldspar	20
			Talc	10
Vitrified clay body	Vitrified		Ball clay or plastic fireclay	95–100
			Small amounts of fluxes	

* Most body formulations include about 5% of milled rejected fired tiles. Other small additions include glass cullet, and pigments where coloured or speckled bodies are required.

provide wear resistance in floor tiles. Fashion dictates whether plain smooth glazes or rustic textures are in demand.

Frits and ceramic colours are made almost exclusively by specialist firms. Colour uniformity and the ability to reproduce previous colours in precise shades is a major problem in the tile industry. A colour comparison test is widely used as a basis for acceptable ware. Besides colour, the physical properties of major interest in tile–making are density, coefficient of expansion and softening temperature.

Glazes can be applied in a variety of ways. Press glazing applies a dry glaze onto the green tile body at the same time as it is being compressed into its mould. For this process, the glaze is dried and granulated in a spray dryer.[7] Dry glazing is usually applied to green tiles that have been conditioned by a sizing solution, then finished in a single firing cycle. Similar glazing machines are used for the wet glazing of tile bodies for single or multiple firing.

Tile decorating techniques include hand painting, transfers and screen printing. Hand painting has long been an art in southern European countries where traditionally it was done on the raw glaze. Increasingly, it is now being done on glost ware which facilitates storage and transport with minimal damage. Hand painted transfers are an indirect hand painting technique that doesn't require the artist to spend long hours in the factory. However, printing, using the silk screen, is the principal tile decorating process today. Up to four colours can be printed by the indirect screen process, permitting either underglaze or onglaze decoration. When there are more than four colours, transfers are usually necessary.

Silk screen printing requires the preparation of printing media and colour in suitable grinding mills,

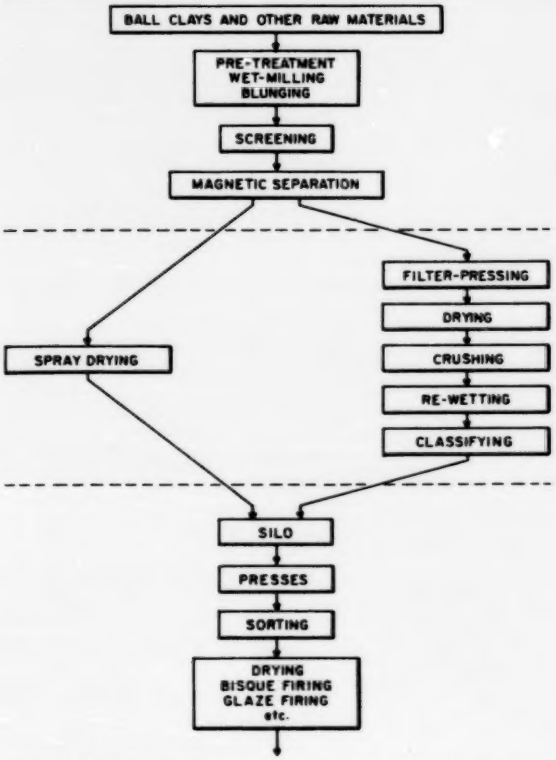

Figure 8.2 Unit operations associated with wet preparation compared to spray drying.

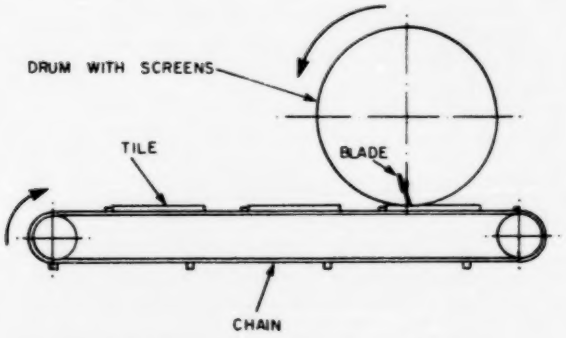

Figure 8.3 Rotary screen printing of tiles.

resulting in a paste with predetermined rheological properties and consistency. Screen printing units can operate either periodically or continuously. Flat screen printers are periodic and can print single or several tiles at the same time, maximum output being about 100 tiles per minute. Continuous rotary screen printing (Figure 8.3) can normally produce 130 to 210 tiles per minute, but the system is often limited to two colours because of high operational speeds and slightly lower precision.

A more detailed discussion of tile decorating is given by Drews.[4]

ONTARIO PRODUCERS

Until 1982, there were four Canadian producers of ceramic floor and wall tiles. These were D. A. White & Co. Ltd. in Kingston, H and R Johnson (Canada) Ltd. in Hamilton, Maple Leaf Ceramic Industries Ltd. in Montreal, and Polyker Inc. in Becancour. D. A. White, Polyker and H and R Johnson (Canada) Ltd. have since ceased operation. H and R Johnson was importing 400,000 to 600,000 m² of bisque annually for conversion into semi-decorated wall tiles.[1]

Three new Ontario producers in 1985, Windsor Ceramic Tile Canada Ltd., Clifton Ceramic Tile and Great Lakes Ceramics, are described on the following pages. A list of the addresses of the operating tile plants is given at the end of this chapter.

WINDSOR CERAMIC TILE CANADA LIMITED

A major addition to Canada's productive capacity for floor and wall tiles was the establishment of Windsor Ceramic Tile in Windsor. It commenced operation in 1985. Total capital investment was said to be $32 million.

Making use of an existing building containing 12,000 m² of floor space, the all new production equipment was engineered and supplied by the German firm of Riedhammer Industrieofenban GmbH. The plant incorporates the latest foreign technology in its process.

A large covered storage area contains stockpiles of Pennsylvanian-age underclay from the Canton area of northeastern Ohio, and surface clay from the McGregor quarry of Allied Chemical of Canada Ltd., east of Amherstberg. Initial production runs were performed using a batch consisting of Ohio clay, surface clay from the McGregor quarry and nepheline syenite.

The clays are reclaimed by front-end loader and proportionally fed to a hopper which feeds two flint pebble mills for wet grinding. They are discharged to one of two large concrete agitator tanks 6 m deep, separated from each other by filter screens. Final chemical and mineral additives are introduced and mixed at this point. The slurry, at 60 percent solids, is pumped to the Dorst spray dryer 20 m high. It is gas fired to 500°C, reducing moisture content to 8 percent, and is capable of evaporating 3,000 litres of water per hour for a pro-

duction of 4.5 tonnes of pelletized granules per hour. These are stored in two 70–tonne silos for ultimate delivery to the tile process.

Seven Dorst tile presses are fed by overhead bucket conveyors. Sixty 5 cm x 5 cm tiles can be pressed with each cycle and transferred to the glazing conveyor by suction pick–up (Photo 8.2). Glazes are applied wet in a spray hood that encloses the conveyor (Photo 8.3). Fifteen colours, including five decorator colours, have been developed for the

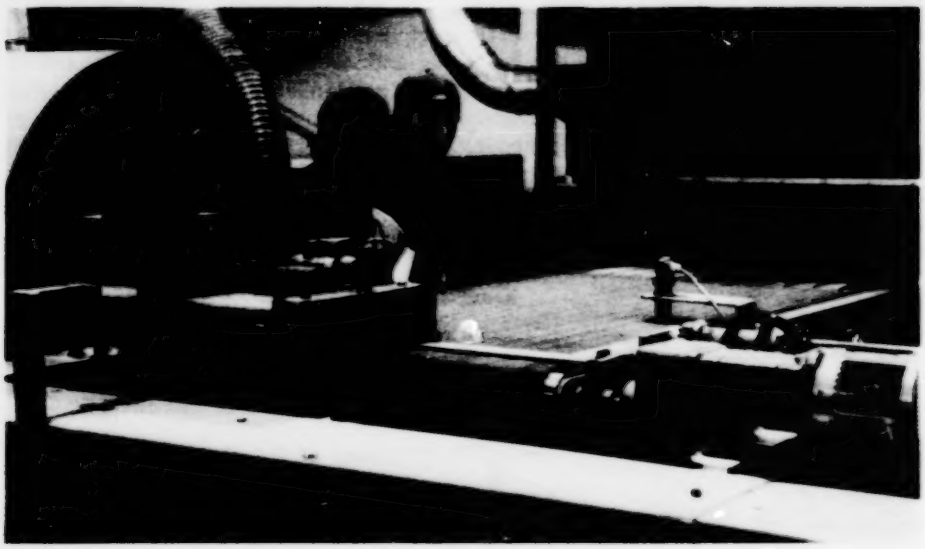

Photo 8.2 Tile press and pneumatic transfer arm. Windsor Ceramic Tile Canada Ltd.

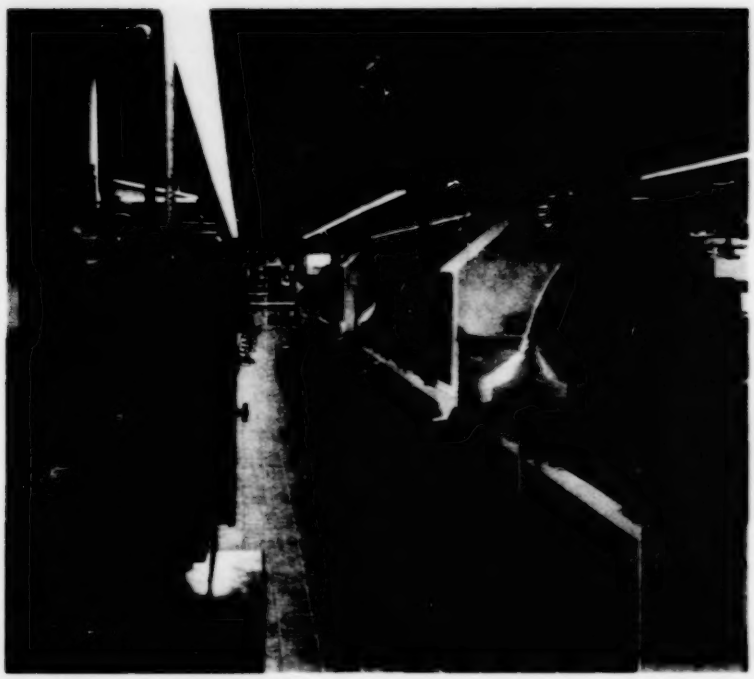

Photo 8.3 Glaze hood. Windsor Ceramic Tile Canada Ltd.

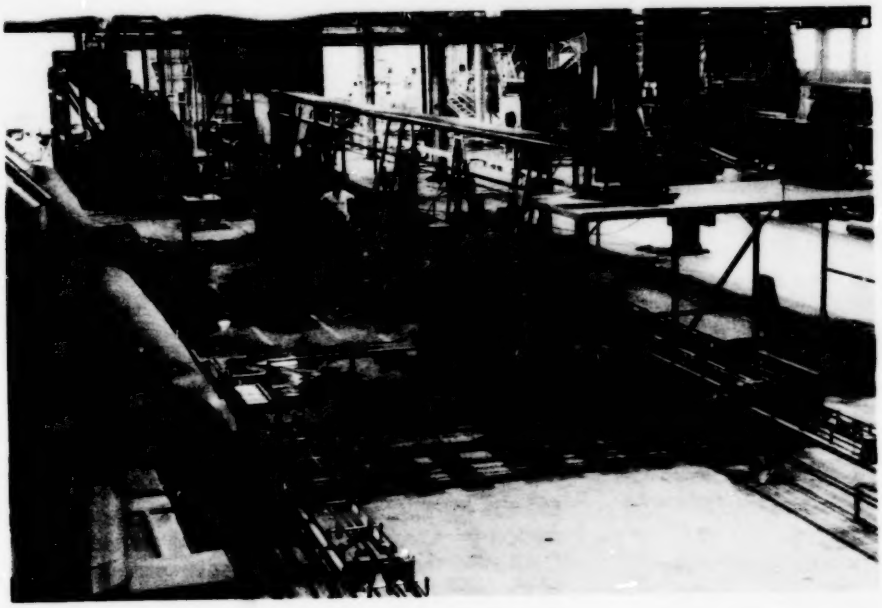

Photo 8.4
Production line at Windsor Ceramic Tile Canada Ltd.

semi–matte and bright glazed series. Pastel, antique and swimming pool series are under development.

There are three fast–fire, sled–type, gas–fired tunnel kilns, each of which provides the combined functions of preheating, firing and cooling. The firing cycle is 35 to 70 minutes, depending on the size of the tile. Peak firing temperatures are about 1200°C and each kiln is capable of producing nearly 3,000 m² of tile per day.

Finished tiles are automatically removed and forwarded for inspection, sorting and packing. There are four lines (Photo 8.4) for mosaic preparation, and twenty staff on each line affix tiles to rayon backing in various size units.

Although initial production will focus on glazed mosaic, both bright and matte, the company's product line will also feature a glazed texture series, unglazed porcelain mosaic, porcelain floor tile and quarry tile. Ultimate plant capacity is expected to reach 2.3 million m² of tile per year. Production will be predominantly in the popular 5 cm x 5 cm, 7.5 cm x 7.5 cm, and 10 cm x 10 cm sizes. The plant is expected to employ 175 year round.

An extensive research laboratory, including a smaller scale complete duplication of the production lines, is available for company research and contract studies.

GREAT LAKES CERAMICS

Great Lakes Ceramics is a new company that, in 1985, leased the Thunderbrick plant at Rosslyn, 10 km west of Thunder Bay. Great Lakes Ceramics expect to start production of on–glazed quarry tile in 1986. They anticipate a starting production rate of ~2 million square feet/year (186,000 m²). The tiles were to be made using a stoneware clay from Rockglen in southern Saskatchewan instead of the local clay and shale which had not proved suitable for Thunderbrick in their attempt to make both bricks and split floor tiles. Local feldspar was being considered as a flux to reduce the cone 9–10 firing range of the stoneware clay.

The Thunderbrick plant was engineered and designed by the German firm Lingl in 1976 at a cost of $4.8 million.[5] It includes some crushing, grinding, screening and drying equipment which was necessary for shale processing, but may not be needed with the Saskatchewan clay. An automatic batch weighing system will, however, be used in the production of split tiles. A J.C. Steele wet pan mixer will be used with or without a pug mill, discharging to a Breitenback extruder. Extruded tiles will be conveyed on pallets to a holding room and dryer.

The dried tiles will be stacked on kiln cars by a Lingl setting machine. The fibre–lined Lingl tunnel kiln is top–fired with gas and is 85 m long. Paired tiles will be split after firing.

CLIFTON CERAMIC TILE

The plant, previously owned by D. A. White & Co. in Kingston, closed in 1982. It has since been re–opened as Clifton Ceramic Tile, owned by Pilkington Ceramic Tile.

The plant operation has remained essentially the same as that used by the previous owners. The equipment from the former operation is in use with some upgrading and improvements effected. Process improvements and increased automation have allowed the new owners to substantially increase the production throughput per worker. They are presently operating with a staff of 30–40, approximately 40% less employees than under D. A. White's operation.

Clifton Ceramic produces commercial floor tile, both glazed and unglazed. Process specifics and production rates are considered proprietary information and are not available for publication.

The company at present uses imported clay using the same sources as D. A. White previously. They have also been involved in work investigating the potential of several samples of northern Ontario clay for tile production. This work has constituted laboratory testing and small–scale production tests. At present, the clays are not commercially mined but the testing performed has indicated that future development is warranted.

PRODUCTION AND CONSUMPTION

World production of ceramic floor and wall tiles was about 700 million m² in 1983, originating from the countries listed in Table 8.5. Italy's dominant position accounts for about 60 percent of West European production. Italy's annual production in 1950 was 7 million m²; in 1977 it was 260 million m², a 37–fold increase.[4]

TABLE 8.5 MAJOR PRODUCING COUNTRIES FOR CERAMIC FLOOR AND WALL TILES.(9)

	Percent of World Production
Italy	37
Japan	12
Brazil	12
Spain	10
Germany	7
France	4
U.S.A.	4
All Others	14

Foreign technology in tile–making, especially in France and Italy, has concentrated on increased automation and computerized process control. This has led to higher production yields, closer control of the process, thereby increasing tile quality and a reduction in manufacturing cost by reducing labour expenses. By incorporating these improvements, as in the Windsor Ceramic Tile plant, Canada can hope to improve its competitiveness in the world market.

Market demand for ceramic tile in Canada increased at an annual rate of 7 percent from 1976 to 1980, reaching a level of 9.3 million m² in 1981. By 1985 it was estimated at 12 million m².[10]

A federal study of the ceramic tile industry in Canada in 1982 is the source of the following information on Canada's production and consumption.[1] Until 1982 there were four Canadian producers, two in Ontario and two in Quebec. These were:

- D. A. White & Co. Ltd., Kingston,
- H and R Johnson (Canada) Ltd., Hamilton,
- Maple Leaf Ceramic Industries Ltd., Montreal,
- Polyker Inc., Becancour.

D. A. White & Co. Ltd. of Kingston ceased operations in 1982. It had an annual capacity of 400,000 m² of ceramic floor tiles.

H and R Johnson (Canada) Ltd. of Hamilton was importing bisque from its parent company and converting it to semi–decorated wall tiles. Its annual capacity was about 500,000 m², 80 percent for export to the U.S.A.

Maple Leaf Ceramic Industries Ltd. of Montreal, a wholly owned subsidiary of Olympia Floor and Wall Tile, was making plain 10.8 cm x 10.8 cm wall tile. Plant capacity was about 700,000 m² annually.

Polyker Inc. of Becancour went into bankruptcy in 1982. It was the most modern Canadian plant, equipped with a good tunnel kiln and a new fast firing production line which was nearly completed. Annual production of about 700,000 m² of glazed and unglazed floor tiles was anticipated.

Total Canadian capacity with these four plants operating was about 2.3 million m², but with both floor tile plants closed, capacity was halved and limited to wall tiles. Likewise, employment in the industry was halved to about 170. And since half of domestic production was exported to the U.S.A., 95 percent of Canada's consumption was imported.

TABLE 8.6 ONTARIO IMPORTS OF CERAMIC TILE BY COUNTRY 1984.(8)
Quantity in m²

Country	Tiles, ceramic, floor and wall, unfinished, 6 cm x 6 cm	Tiles, ceramic, floor and wall, 6 cm x 6 cm and over	Tiles, paving, earthenware	Tiles, quarry, earthenware	Tiles earthenware, 6 cm and over, square, unfinished	Tiles, earthenware not elsewhere specified
United Kingdom	166	113,290	22,241	21		16
Malta	0	0	0			1
Denmark	0	2,314	0	0	0	0
France	0	19,557	0	0	0	0
Germany, West	1,486	79,158	31,378	0	860	16
Greece	0	636	0	0	0	0
Italy	47,686	2,230,035	0	3,720	0	0
Netherlands	0	23,303	0	714	0	26
Portugal	0	132,868	0	0	0	0
Spain	33,315	1,667,527		15,108	1,711	8
Sweden	0	11,012	0	0	0	0
Israel	0	117,583	0	0	0	0
Sri Lanka	0	4,042	0	0	0	0
Hong Kong	0	0	0	0	0	12
Japan	219,756	465,662	0	0	736	2
Korea, South	77,673	0	0	0	0	0
Taiwan	0	0	0	0	0	1
Thailand	4,013	7,926	0	0	0	0
Brazil	0	101,782	0	0	0	0
Mexico	0	18,352	0	0	0	23
United States	2,835	9,488	1,602	9,489	0	108
Total Quantity	386,930	5,004,536	57,221	29,052	3,307	213
Value ($000)	3,044	33,457	591	244	34	-

New production of split tile in 1985 by Great Lakes Ceramics at Thunder Bay, and floor and wall tiles by Windsor Ceramic Tile Canada Ltd. will largely be exported to the U.S.A. Clearly, an opportunity exists for greater production for domestic markets.

Production in the U.S.A. accounts for about 60 percent of domestic consumption. The rest is imported mainly from Japan, Italy, Mexico and Korea. A breakdown of Ontario tile imports by country is given in Table 8.6.

Ceramic floor and wall tiles are enjoying a high level of consumer demand in North America. Italian tile makers believe the U.S.A. has the greatest potential for growth in the world today, if only because of the present very low level of consumption. Per capita use of ceramic tile is nearly twice as high in Canada as in the U.S.A., six times as high in Brazil and more than ten times in Italy.

During the period 1976–1981 new housing units in the U.S.A. increased only 2 percent, while sales of ceramic tiles were up 14 percent. However, remodelling of older homes increased about 16 percent per year, consuming more ceramic tiles than new construction. And because of faster setting adhesives and grouts, the do–it–yourself sector now represents 20 percent of the total U.S.A. market.[4, 6]

MARKETING

A good sales distribution network is essential for any tile producer. Olympia Floor and Wall Tile Company enjoys about 70 percent of the Canadian market; Central Supply Company 10–12 percent. Only 10 percent of Olympia's volume is manufactured by its Montreal subsidiary, Maple Leaf Ceramic Industries; the rest is imported. Central Supply imports most of its tiles, but markets some from H and R Johnson. D. A. White and Polyker had their own distribution network. Some 30 to 50 additional firms across Canada are independent distributors.[1]

In the U.S.A. there are about 2,500 distributors of ceramic tiles, led by an effective Ceramic Tile Distributors' Association. Their first premise is that markets for ceramic tile exist wherever there are construction surfaces, old or new. Furthermore, any wall or floor, indoor or outdoor, can benefit from ceramic tile. The Italian tile trade association has

invested in a multimillion dollar consumer advertising program aimed at architects, designers, distributors and homeowners in the U.S.A. in an attempt to sell more Italian–made tile.[6]

With the increased cost of petroleum–based products, ceramic floor and wall tiles have become very cost competitive with other types of floor coverings in recent years.

ENERGY AND ECONOMICS

With the exception of Windsor Ceramic Tile and Great Lakes Ceramics, Canada's tile plants are old and inefficient. In general, they use twice as much energy as European plants, but because energy is less expensive in Canada, it constitutes about the same proportion of operation costs, about 10 percent.

Using natural gas, the Canadian energy cost in 1982 was about $1 per m² for fast firing kilns and $0.65 to $1 per m² for traditional tunnel kilns. A recently built tunnel kiln at the Polyker plant in Quebec has an energy cost of nearly $2 per m² using propane gas as the fuel.[1]

Direct and indirect labour costs in Canada's older plants represented up to 40 percent of total operating cost as compared to 20 or 25 percent in a modern plant. According to Bergeron,[1] about 400,000 m² of tiles are produced by a labour force of 100 in Canada, whereas the average in Europe is 700,000 m² per 100 employees. Current European practice is to rebuild completely and modernize tile plants after seven years,[6] a practice that is facilitated in Italy by government taxation that allows complete amortization of equipment over a period of six years.[1]

A modern tile plant today represents a considerable investment. The all new Windsor Ceramic Tile plant at Windsor, Ontario, cost approximately $30 million in 1985.

PROBLEMS AND OPPORTUNITIES

Many of Canada's floor and wall tile plants require updating. Old equipment, processes and technology mean higher energy, labour and maintenance costs relative to major foreign competitors. However, new production facilities at Windsor, and a rejuvenated split tile facility at Thunder Bay, should, for the first time, make the bulk of Ontario's production reasonably competitive with other world producers.

Unfortunately, all of Ontario's plants depend on imports of raw material: Windsor Ceramic Tile uses ball clay from Ohio; Great Lakes Ceramics uses stoneware clay from Saskatchewan; and H and R Johnson imports bisque. Escalating transportation costs have resulted in raw material costs approaching 40 percent of total operating costs in some instances, a value three to four times higher than foreign competitors. To be competitive, raw material cost, including transportation costs, should be less than $2 per m² of finished tiles.

Ontario has the potential to be self–sufficient in these kaolin–type clays, through its undeveloped resources in the Moose River Basin of northeastern Ontario. However, their remoteness from major tile markets would not likely allow for any improvement in the transportation cost factor.

More than half of Ontario's production of floor and wall tiles is exported to the U.S.A., leaving a large domestic market dependent largely on imports. In spite of two new producing facilities in 1985, an opportunity exists for much increased production for the rapidly growing Ontario market.

However, to be successful, new plants should seek foreign technical assistance and management. Most of the more advanced technology and equipment originates in Italy and Germany. Where sales of Italian tiles have been particularly strong, the trend today is for Italian tile markets to establish new production facilities in that area as a means of assuring their continued dominance in that market.[6]

As in many of the major European tile producing countries, government assistance in aspects of taxation, research and development, and international sales promotion, is a major asset in the development of a strong industry.

APPENDIX — FLOOR AND WALL TILE MANUFACTURERS IN ONTARIO (1986)

1. Clifton Ceramic Tiles Inc.
   Box 578
   60 Cassidy Street
   Kingston, Ontario
   K7L 4X1
   (613) 549-5932
2. Great Lakes Ceramics
   RR #5 Rosslyn Road
   Thunder Bay, Ontario
   P7C 5M9
   (807) 939-2645
3. Windsor Ceramic Tile Canada Ltd.
   5550 Ojibway Parkway
   Windsor, Ontario
   N9C 3Y3
   (519) 969-5050

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Chapter 9 — Sanitaryware

INTRODUCTION

There are three manufacturers of ceramic sanitaryware fixtures in Ontario (Figure 9.1), namely:

- American Standard Products of Toronto
- Crane Canada Inc. of Trenton, and
- Waltec Bathware of Cornwall.

Plant addresses are given in an appendix at the end of this chapter.

The Toronto–based American Standard plant is the largest of the three, and supplies a nationwide market from this single location. The Crane Canada Inc. facility in Trenton is one of three plants operated by the company, and is designed to meet the market demands of central Canada plus some U.S. export. (The company's Quebec and British Columbia operations meet the market requirements of eastern and western Canada, respectively). Waltec Bathware of Cornwall is the smallest manufacturer, and satisfies a regional market.

Each of the manufacturers produces traditional sanitaryware product lines by slip casting techniques (solid–casting and drain–casting). The principal ingredients of the casting slips are china clays and ball clays which are imported from the southern states of the U.S.A., together with nepheline syenite and silica which are obtained locally.

All products are single fired glazed pieces, all glazes being prepared 'raw' (as opposed to fritted prepared glazes). At this time the industry is experiencing no environmental pressures, although care is taken to control effluents from the glazing operations to prevent the escape of heavy metal ions to the local environment.

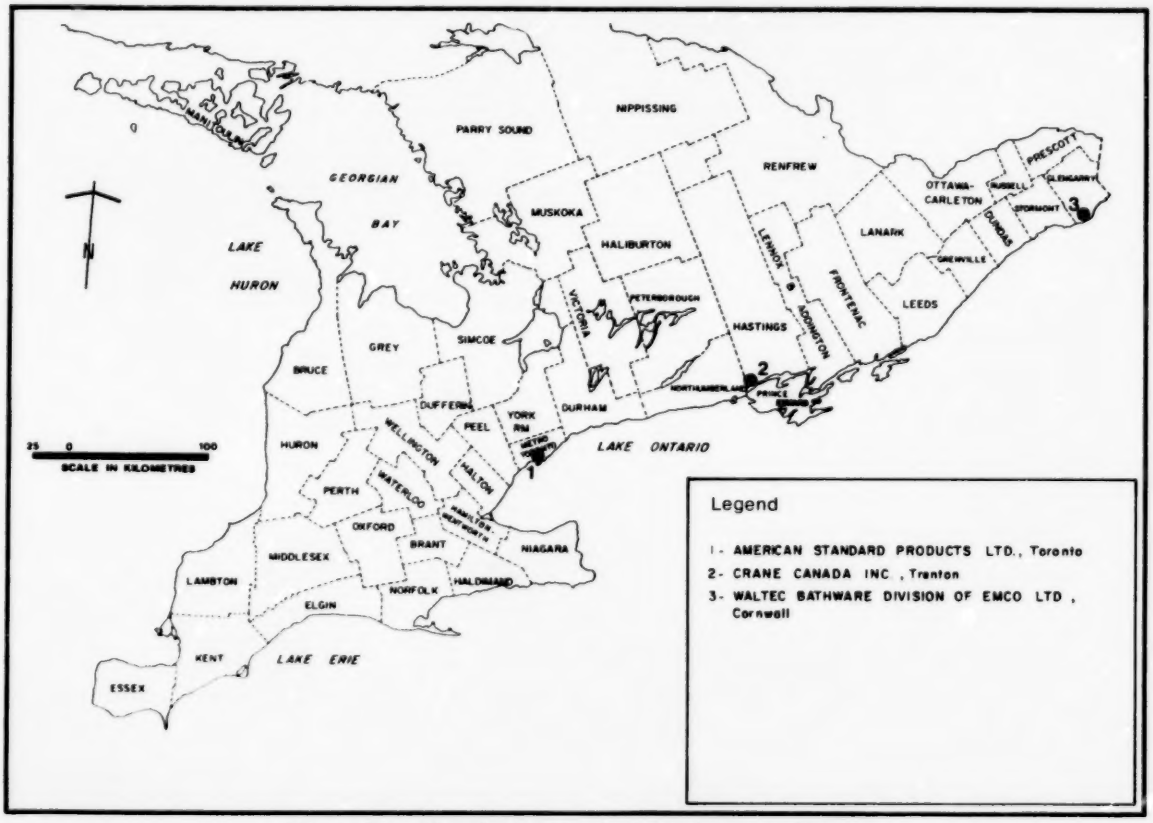

Figure 9.1 Manufacturers of sanitaryware in Ontario.

The industry is also fully aware of the Ministry of Labour guidelines on the hazards of silica dust and has taken steps to meet the required standards.

MANUFACTURING TECHNOLOGY

SLIP CASTING TECHNIQUE

Sanitaryware is manufactured exclusively by traditional slip casting techniques (Figure 9.2). Fabrication is achieved by pouring the desired quantity of an appropriate slip (or slurry) into a one–, two– or more part plaster mould and allowing the slip to remain in the mould for a "casting–up" period. During this time the mould, which is porous, absorbs water from the slip adjacent to its walls such that an even layer of clay gradually builds up over its entire internal surface. The casting–up period is selected so as to provide a clay layer of appropriate thickness. At the end of this period the remaining slip is poured off and the mould, and casting which remains in it, are dried sufficiently to enable the mould to be dismantled and the casting removed without damage.

Solid items can be similarly manufactured by using double wall casting techniques, where the slip is poured between two parts of a mould (one male and the other female). This ensures not only that both the internal and external surfaces will be clearly defined, but also that the wall thickness will be precisely as required.

For highly complex pieces, such as a toilet bowl or bidet, different components may be cast separately and the final product assembled by sticking the individual pieces together with clay slip after they have been removed from the plaster moulds. Products are subsequently dried, surface finished, glazed and fired.

Although the above description is relatively simplistic, it can be seen that slip casting is a fairly lengthy process in which the controlling sequence is the 'casting–up' time. This particular property is governed by a number of variables as follows:

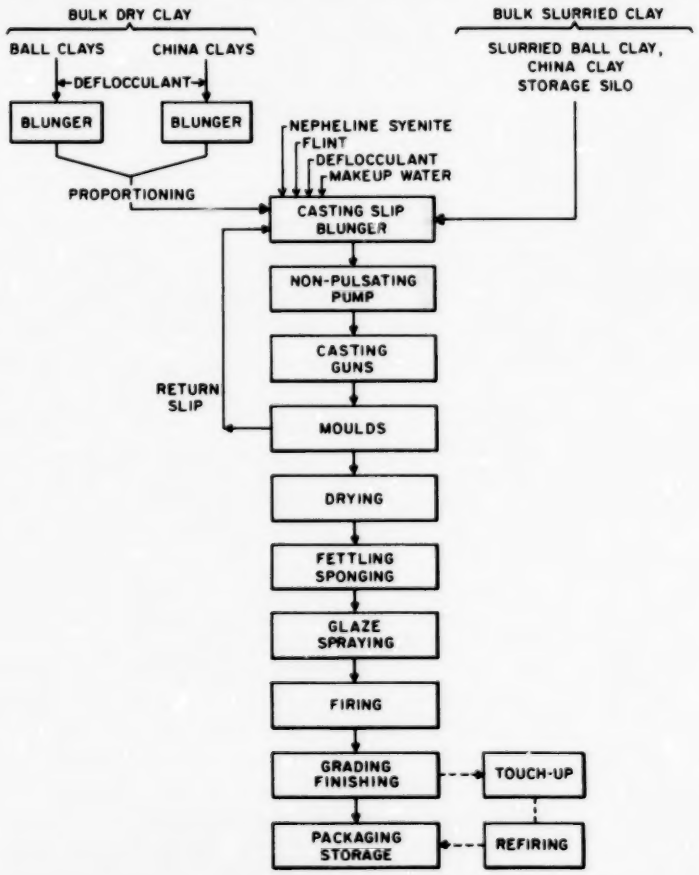

Figure 9.2 Process flow chart for sanitaryware production.

i. mould porosity,

ii. slip properties,

iii. raw materials type and particle size distribution.

Of these, items (ii) and (iii) are very closely controlled during slip preparation stage (in the 'slip–house') where the raw materials are blended.

PARAMETERS GOVERNING SLIP CASTING PROCESS

Mould Porosity

The removal of water from clay–water slips by plaster moulds is achieved by capillary action through inter–connected pores between the lath–like gypsum crystals which make up the mould. These pores are sufficiently small to prevent migration of the common solid particle constituents of the slip into the body of the mould. The absorption characteristics of plaster moulds, together with their hardness, durability and abrasion resistance, are a function of the plaster type and ratio of plaster to water used in fabricating the mould. Whilst good casting plaster moulds exhibit high absorption rates and good compressive strength, their hardness and abrasion resistance is not especially good. Consequently, for pottery manufacture on a large scale, a compromise between high absorption rates and good durability is required if the moulds are to exhibit reasonable working lifetimes (e.g. 100 casts).

In order to achieve reasonable production rates, moulds need to be used repeatedly. This requires that they be dried between use; this can be a problem when multiple casts (i.e. 2 per shift) are required for a single mould. Thus, mould porosity must also be designed to facilitate drying (evolution of water) as well as absorption of water.

Slip Properties

The rate at which the clay layer builds up at the surface of the plaster mould is, of course, also highly dependent upon such slip properties as concentration (or specific gravity) and fluidity. The more concentrated the slip, the more rapid is the deposition of the clay layer. However, to facilitate handling and in order to obtain a smooth cast finish, the slip must also exhibit reasonable fluidity; thus a compromise must be obtained between the concentration and the fluidity of the slip for optimum casting. This is aided by the use of deflocculating agents, such as sodium silicate and/or alkali metal salts, which reduce the viscosity of the slip, thus allowing the concentration to be increased at the same time that fluidity is improved. Without the use of deflocculants, satisfactory fluidity could only be obtained at relatively low slip densities, and if used in this form, long casting times and inferior products would be obtained. Consequently, all casting slips utilize deflocculants.

An additional important property exhibited by ceramic slips (particularly clay–based ones) is thixotropy. This term describes the ability of a slip to 'thicken' on standing once agitation has been removed. This 'thickening' effect is important in slip casting in that it stabilizes the slurry during the time that it is in the mould and also provides a network for the migration of water through the cast layer on the surface of the mould and accelerates casting time. Most slips exhibit natural thixotropy, but those which are deflocculated by very powerful deflocculants exhibit very little. In the high productivity environment of a sanitaryware plant this property requires rigid control. This is achieved by careful control of the slip concentration, raw materials selection and deflocculant addition plus the addition of flocculating ions. All things being equal, the higher the slip density, the greater the thixotropic effect.

For satisfactory casting, a slip must therefore possess certain flow properties. While no universal rules can be stated, it has been found that many casting slips operate best with a fairly high fluidity and a moderate thixotropy. Since some thixotropy is required, sodium silicate is rarely used alone as a deflocculant in sanitaryware manufacture, but is usually added as a mixture with sodium carbonate and calcium sulphate which produces the thixotropic effects.

Raw Materials and Particle Size Distribution

Once a layer of clay has been deposited upon the surface of a plaster mould during the slip casting operation, the rate of removal of water from the clay slip becomes not only a function of the absorption characteristics of the mould materials, but also of the permeability of the deposited clay layer to the water film. In well deflocculated systems, the plate–like clay crystals tend to form flat oriented impermeable layers. Thixotropy, together with the incorporation of materials of varying particle size, greatly aids the permeability, or draining characteristics, of the cast layer. Materials which are too coarse or dense should not be incorporated, however, since they may settle in the mould, producing a non–uniform cast product and subsequent cracking on drying.

Most common clay minerals are extremely fine, and exist in a narrow size range, usually well below 2 μm in diameter. Slip casting of single component

systems of such materials gives rise to very slow casting rates and results in brittle casts and poor drainage due to close packing of the clay–particles contained within the cast layer. Consequently, most slip casting formulations consist of a blend of clay types (and size fractions). China clays (kaolinites) provide coarse fraction clays, while ball clays contribute fine fraction materials (plus a contribution to green strength).

FINISHING AND FIRING

Subsequent to the slip casting operation, sanitaryware products are dried and surface finished (to remove flash and mould–seam lines). The finished ware is then glazed, invariably by spraying techniques using raw glaze formulations (i.e. glazes prepared from slurries of natural minerals such as clay, feldspar, flux, opacifiers such as zirconium silicate, and pigments). Firing is usually conducted in muffled kilns; both continuous tunnel and intermittent types are used. Some companies fire simple pieces in direct–fire kilns (no muffle), but this practice is not universally accepted.

DEVELOPING TECHNOLOGY

The sanitaryware industry has several emerging technologies which may find commercial application in the near future. Most of these are essentially aimed at productivity improvements, minimizing production costs by:

- improvement of mould turnaround time,
- improvements in mould life,
- minimization of fuel costs,
- increased automation.

In addition to the above, product quality improvements have been and are being achieved as a result of:

- changes in slip formulation,
- raw materials selection,
- raw materials blending,
- improved quality control.

The major technologies which are likely to impact or are currently impacting upon the sanitaryware industry are described below.

CONVERSION OF CLAY SUPPLIERS TO BLENDED SLURRIES

Traditionally, the sanitaryware industry purchased all of its raw materials in dry powdered form and prepared the required clay slips according to standard formulas by weight–batching techniques. This technique, though well tried and tested, is prone to errors, and quality control can be a problem as the slips 'age' and the flow properties and particle size distribution change.

In recent years (since about 1970) major clay suppliers in the southern states of the U.S.A. have moved to supplying the clays in slurry form[6, 8] (duplicating the supply system which they have used for the paper industry for many years). Probably the leaders in this field are Cyprus Mines, the Kentucky–Tennessee Clay Company, and H. C. Spinks Company. In all cases, the supplier provides a custom, partially deflocculated, blended clay slurry of china clay (at 70 percent solids), or ball clay (at 60 percent solids), together with specifications and quality control data (viscosity, etc.) for each car supplied. Aging effects and slurry stabilization take place during transit to the user industry such that on arrival at the sanitaryware plant, the user effectively only needs to adjust the formula by adding make–up water and the non–plastic ingredients of silica and feldspar (nepheline syenite) together with final adjustment of the flow properties by addition of deflocculants (and flocculants) before the slip is ready for use. The slurried raw materials are carefully controlled and guaranteed to perform. This factor is effectively eliminating the practice of operating a conventional slip house.

A major modification of this technology is currently under development by the H. C. Spinks Company, which entails not only custom blending of selected clay types but also computer controlled custom blending of optimized particle size.[10, 4, 2] It is reported that this development will be operational in 1986.

Two of the three Ontario plants currently receive all of their clay supplies in slurry form; the third receives a portion of its raw material in this form and expects to increase this proportion in the near future. It is reported[8] that approximately 50 percent of the sanitaryware plants in North America had converted to slurry systems by 1981.

AUTOMATED CASTING SYSTEMS

Automated casting systems have been under evaluation and development for several years. Essentially, the systems developed are based on the same principle as manual casting except that the machine contains banks of mould carriers on an indexing device upon which the moulds automatically proceed through the following cycle:

a. filling of moulds with slip,
b. casting up,
c. discharge of slip,

d. drying of cast in mould,

e. removal of cast (a manual operation),

f. drying of mould.

Automated casting systems reputedly show the following advantages over manual casting operations:

a. increased productivity per operator (a single operator is generally required per machine),

b. requires only semi–skilled operators,

c. reduces space requirement,

d. reduces mould handling, thereby increasing the working life of moulds,

e. reduces losses of discharge slip,

f. improves consistency and quality of product, by utilizing a standard casting–up time which is mechanically controlled.

If however, conventional clay slips with long casting–up times are used, then for automatic systems to be effective, physically large (long) machines are required together with the use of a large number of moulds at any one time. Thus, in order to gain maximum advantage and saving from automatic casting systems, short casting–up periods are preferred.

While the productivity of manual casting is largely controlled by the casting–up time, this is not true for automatic casting systems. Since the moulds are automatically filled and emptied, once in operation the controlling sequence of the equipment is the indexing time (i.e. the rate of advance of each bank of mould carriers). The casting–up sequence is accommodated by adjusting the length of the machine to give the desired cast thickness. Thus, the rate of production depends solely upon the rate of removal of moulds from the carriers, extraction of the ware and replacement of the empty moulds back in the carriers by the machine operator. The indexing time is set such that the machine operator can carry out this sequence of operations for each bank of moulds between each advance.

More recent developments in Japan and, to some extent, in the U.S.A. and Great Britain[1] have seen the use of robots and fully automated plant designs to improve productivity. At this time, information on such systems is proprietary.

PRESSURE CASTING

Possibly the most significant development in sanitaryware manufacture in recent years is the pressure casting technology recently developed in Europe[9] and currently undergoing tests in Europe and North America. This technique uses porous plastic moulds into which casting slips are pumped under a pressure of approximately 2 MPa. The new plastic mould gives rise to superior surface finishes compared to conventional plaster mould with the main production controlling parameters being pressure, wall thickness and the dewatering properties of the slurry itself. In essence, the moulding system works in a manner similar to a filter press. The key benefit of the technology is that products can be produced to higher tolerances in a total cycle time of 6–10 minutes, 24 hours each day. The residual moisture in the product produced is 1–2 percent less than that obtained by slip casting, and as a consequence it can be readily removed from the mould by a pulse of compressed air, immediately after the pressure is released and the surplus slip has been drained.

Thus the technology allows a multiple shift operation using a single machine; flexibility is maintained by a rapid mould changing capability. Less working area is also required, and a single mould will suffice for each shape required (working life is estimated to be multiple thousand mouldings). In addition, heavy manual work is avoided for production of large items.

Such a system provides a solution to many of the productivity problems facing the industry, however it must be recognized that some design changes may be needed to accommodate the mechanics of pressure moulding.

Reports from the industry indicate that this technology is being well received in North America.

ELECTROPHORETIC CASTING

Research has been conducted in Europe on ceramic forming by electrophoretic deposition of clay from slip. A process called "Voluphant"[7] has been developed to compete with traditional slip casting:

Step 1. Two anodes, shaped to form the surfaces of the cast piece are immersed in the slip.

Step 2. A double–sided cathode fits between the anodes leaving a 12 mm electrode gap on either side.

Step 3. Slip is fed into the electrode gap through a hole in the cathode.

Step 4. Deposition is carried out for a number of minutes, the time dependent on the desired wall thickness.

Step 5. The anodes are moved apart and the cathode withdrawn.

Step 6. The two layers of deposit, i.e. on either anode, are pressed together and the piece removed.

It has been suggested that, because of the symmetry of the formed piece, stresses incurred during drying and firing the ware will balance out, and a lower reject rate will result. The process is suited for the manufacture of large pieces of ware.

MOULD AND WARE DRYING TECHNOLOGY

Sanitaryware plants which require multiple casts per shift or per day suffer from serious bottlenecks in turnaround time for drying and handling of the moulds before further use and drying of the green ware in the mould prior to removal and dismantling. A new technology which has been applied to this problem is microwave drying;[5] it has also been used to accelerate casting rates, thus speeding up the total process.

It has been observed that application of microwave techniques can completely eliminate the need for mould drying. Furthermore, in a situation where 2 casts per shift were proving difficult, up to 3 casts were obtained in 1.5 hours using this technology.

Microwave technology is still in the research stage and is experiencing some difficulty being accepted by the industry, although it is certainly attracting some interest.

FIRING TECHNOLOGY

Firing technology continues to be of major interest to the sanitaryware industry, both from the aspect of energy conservation and from improved product quality. As previously stated, firing technology usually involves muffled tunnel kiln firing. However, it has been suggested by manufacturers that different kiln systems would be preferred if new plants were to be commissioned today.

Direct fire roller hearth kilns are cited as providing the most modern technology where total firing times (cold to cold) of 8 hours are quoted.

ONTARIO OPERATORS

AMERICAN STANDARD PRODUCTS

The American Standard pottery in Toronto is a subsidiary of a U.S. parent company. The pottery was founded in 1918 as a spin–off industry of "Cast Iron Sanitaryware". This plant services the total Canadian market, manufacturing a full range of products in both price and sophistication.

Raw Materials

China clays (kaolin) are imported from Georgia, (U.S.A.) and also from Great Britain. Ball clays are imported from Kentucky and Tennessee in the U.S.A. Nepheline syenite is obtained from Ontario. Silica is obtained from Ontario Slip Modifiers and deflocculants are obtained from local suppliers.

Currently, the ball clay is obtained in slurry form, whereas the china clay is received dry and is used to customize, modify and control slip properties.

Manufacturing Process

At present, the company operates a standard 'slip house' body preparation procedure which is labour intensive. Components are batched by weight and pneumatically conveyed to the mixing operation. The prepared slips are closely monitored and controlled prior to delivery to the casting shop where manual, semi–automatic and automatic casting techniques are employed (depending on the product line).

Slip casting time is approximately 1 hour, with a cycle time of approximately 3–1/2 hours from assembly, casting and dismantling of mould. Targets of 2 casts per shift are attained for all but large–size products which are subjected to a single cast cycle. Mould drying is seen to be a serious bottleneck when meeting such production rates.

After dismantling of the mould and removal of the ware, the products are dried in gas dryers and then subjected to surface finishing and inspection. Both manual and automatic techniques for surface finishing are used. All products are subsequently spray glazed on conveyors.

Raw glaze formulations may contain clays, feldspars, silica, zinc oxide, barium carbonate, talc, whiting, wollastonite, zirconium silicate and pigment stains. Such formulations, although providing good adhesion to the body, can be a source of problems in fast firing cycles.

Firing is conducted in five tunnel kilns, one of which is a 'direct–fire' kiln, and four of which are muffle kilns. Two of the kilns are retained for refire purposes, as is a single intermittent direct fire kiln.

General Observations

In general terms, the supply of raw materials by a single source is seen as a problem. Commercial users generally prefer to maintain at least two sources of supply for key ingredients. The recent acquisition of I.M.C.'s nepheline syenite operations by Indusmin may be a significant source of concern. It is

interesting to note that if it were available, a potassium feldspar would be preferred for slip casting over nepheline syenite.

The supply of clay slurries from U.S. sources is not seen as a problem; quality is high and competition between suppliers is ensuring continuity of supply and good service.

CRANE CANADA INC.

Crane Canada Inc. is a division of Crane Corporation of the U.S.A. The Trenton pottery was constructed in 1968 and became operational in 1969. Construction was part of Crane Canada's philosophy of using small production plants to serve a regional market. Consequently, this plant essentially serves central Canada (Ontario and parts of Manitoba), together with some export markets in the U.S.A.

The Trenton pottery was originally designed to specifically use only clay slurry raw material and was the first of its kind pioneering the technology. The purpose of the plant was to produce high volumes of a limited product line. It produces up to 300,000 items per year with a staff of approximately 100.

Raw Materials

China clays are imported from Georgia, U.S.A. Ball clays are imported from Kentucky and Tennessee. Silica is obained from Ontario and Quebec sources. Nepheline syenite is obtained from Ontario sources.

The clays as previously stated are purchased in premixed slurry blends of three kaolin clays and three ball clays. Every car supplied is tested prior to, and after, receiving shipment for quality control purposes. Typically, the following properties are tested: filtration characteristics, deflocculation curve/viscosity, colour, sulphate level, particle size distribution.

Manufacturing Process

The raw materials are directly blunged, further deflocculant is added to the clay slurries, and silica and nepheline syenite are also added; viscosity is then adjusted, and occasionally bagged material is added to adjust particle size distribution.

The prepared slip is delivered to the casting shop where cast times of approximately 1 hour are used. Two casts per shift are achieved using a cycle time–assembly to dismantle of approximately 3 hours. Products are left to air–dry in the casting shop for 24 hours before being force–dried in Langley gas dryers for approximately 12 hours. Ware is subsequently inspected, finished and prepared for glazing.

All items are hand spray glazed, using standard raw glazes, on green ware and fired in a Swindell Dressler gas fired muffle tunnel kiln. Firing times of 18 to 20 hours, cold to cold, are typical. A second direct fire small tunnel kiln is retained for refiring of products.

General Observations

Pressure casting technology, together with other mechanised techniques, require high volume to justify installation; this could prove difficult for smaller plants.

Lavatory bowls marketed to low water use areas may give rise to major design changes resulting in expensive heavy units (4.5 litres nominal water flush) with low recovery.

WALTEC BATHWARE

Waltec Bathware's Cornwall pottery was originally designed and constructed by Eastern potteries in the early 1970s, and later purchased by Waltec Inc., a major Canadian manufacturer of plumbing ware, in the early 1980s. In 1984 Emco, another major manufacturer of plumbing ware, which is a subsidiary of Masco Ltd. in the U.S.A., acquired Waltec. The Cornwall pottery is the only ceramic manufacturing operation within the corporation.

The plant was originally designed to produce high volume, low price sanitaryware; however, this mandate is changing, and the company currently manufactures a broad range of product types and markets its product across the whole country. Products include lavatories, tanks, sinks and bidets.

In addition to the ceramic sanitaryware products manufactured at the Cornwall plant, a complementary range of acrylic bathtubs, whirlpools and shower stalls (in matching colours) are also made.

Raw Materials

China clays are imported from Georgia, U.S.A. Ball clays are imported from Kentucky and Tennessee. Silica is obtained from Quebec sources. Nepheline syenite is obtained from Ontario sources.

The clay raw materials are purchased in premixed slurry blends. Every car supplied is tested prior to, and after, receiving shipment for quality control purposes.

Manufacturing Process

The raw materials are directly blunged in a 5–day storage tank where other raw materials and further deflocculants and property modifying ingredients are added. The slurry is subsequently aged for 5 days prior to use to ensure stabilization of the slip.

The prepared slip is delivered to the casting shop where cast times of approximately 1 hour are used. Two casts per day are standard practice on lavatory bowls, all other products are subjected to a single cast cycle. All casting operations are conducted manually. After demoulding, products are left to air–dry for 24 hours and then force dried using excess heat from the kiln. Dried ware is then inspected and finished and subsequently spray glazed. All glazed ware is essentially raw glazed, although some formulations do contain a small quantity of fritted material. Standard components of the glaze include clays, feldspars, zinc oxide, zirconium silicate, whiting and pigments.

Glazed products are fired in a 90 m long roller hearth kiln and subjected to a fast firing cycle of approximately 11 hours (cold to cold). (Two hundred and twenty bowls and 190 tanks can be fired per day). A direct fire periodic kiln with a 24 hour firing cycle is used for refiring purposes and also to fire complex products and many of the coloured glaze products. Rapid firing in the roller hearth kiln occasionally creates problems of colour and glaze maturation for some coloured products. Approximately 70 percent of the products manufactured are white.

NEW BUSINESS OPPORTUNITIES

Traditionally, sanitaryware fixtures are white or single coloured glazed products with no decoration. Bathroom design trends are currently including a high level of on–glaze decoration for bathroom tiling, and some European companies are responding to this trend by incorporating complementary on–glaze decoration (decals) on their product line.[3] To incorporate a specialty decoration line into a high productivity sanitaryware plant would be a major source of problems, for the operation would require not only additional labour and handling, but also an additional kiln and necessary space.

It seems feasible, however, that a secondary plant or manufacturer could develop this technology and apply decoration to products which have been purchased from a primary supplier. In this way, a small business could be developed in which custom designs and a wide range of "added value" aesthetic designs could be incorporated into what has previously been a 'plain' product line.

APPENDIX — SANITARYWARE MANUFACTURERS IN ONTARIO (1986)

1. American Standard Products
   80 Ward Street
   Toronto, Ontario
   M6H 4A7
   (416) 536-1078
2. Crane Canada Inc.
   420 Sidney Street
   Trenton, Ontario.
   K8V 5R6
   (613) 392-3591
3. Waltec Bathware Div.
   805 Boundary Road
   Cornwall, Ontario
   K6H 5T3
   (613) 933-4511

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Chapter 10 — Electrical Porcelain

INTRODUCTION

INDUSTRIAL OPERATIONS

Three major companies dominate the Ontario–based electrical porcelain business at the present time (Figure 10.1), namely:

- Hamilton Porcelains Ltd. of Brantford,
- Smith & Stone Ltd. of Georgetown,
- Electro Porcelain Company Ltd. of Waterloo.

Each of these companies essentially manufactures a diversified product line of low tension porcelain and special refractory products, and has located a solid market niche.

Up until the late 1970s, Ontario also possessed a very active high tension porcelain industry in the form of: Canadian Porcelains of Hamilton, and Canadian Ohio Brass of Niagara Falls, both of whom manufactured high voltage insulators predominantly for the domestic market. These two companies recently ceased operations, and at the time of writing it has been reported that the Canadian Porcelain facilities have been acquired by Lapp Insulator Company of the U.S.A.

The porcelain ceramic body formulations used by all producers are based on traditional formulations, all of the clay components being imported from the U.S.A., together with some feldspars and talcs. Only silica and nepheline syenite are obtained from Canadian (Ontario) suppliers.

None of the manufacturers currently experiences any environmental problems, and neither do they anticipate any in the immediate future. They are all conscious of current occupational health regulations concerning use of silica dust, and have taken steps to ensure that they meet Ministry of Labour guidelines.

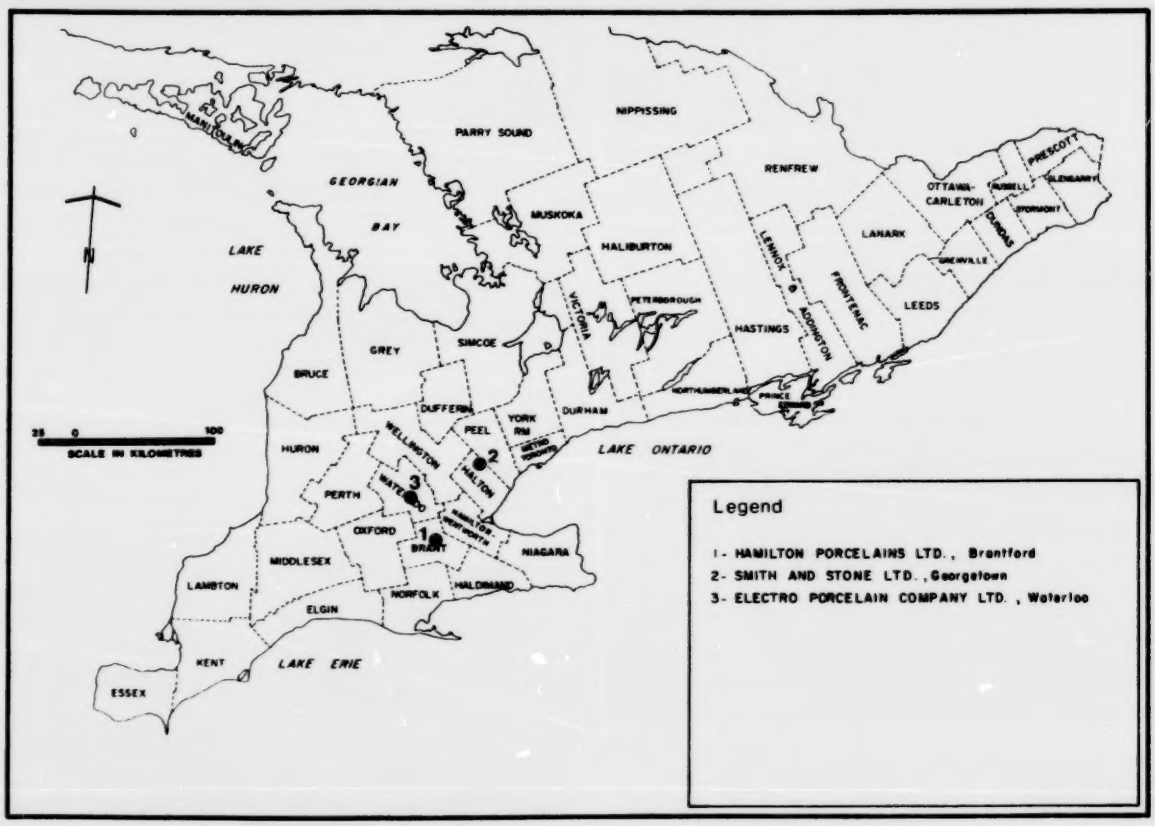

Figure 10.1 Manufacturers of electrical porcelain in Ontario.

PRODUCT DEFINITIONS

Low Tension Porcelain is typically a highly vitrefied body consisting essentially of mullite and quartz crystals embedded in a glassy matrix, the relative proportions of which are adjusted to produce desired properties. The products are manufactured to withstand normal domestic voltages, typical applications being lamp holders, fuse holders, connectors, appliance parts, telephone insulators, and aerial insulators. Items may be glazed or unglazed.

High Tension Porcelain is typically a fully vitrefied body (which exhibits zero water absorption) which is also glazed. The products show excellent resistance to freeze–thaw action and good mechanical strength in both tension and compression. Typical products are suspension insulators for high voltage transmission lines and switchgear. There are basically three types of insulators: tension, post and hollow. These are shown in Figure 10.2. Included in the diagram are typical sizes and mechanical requirements for each.

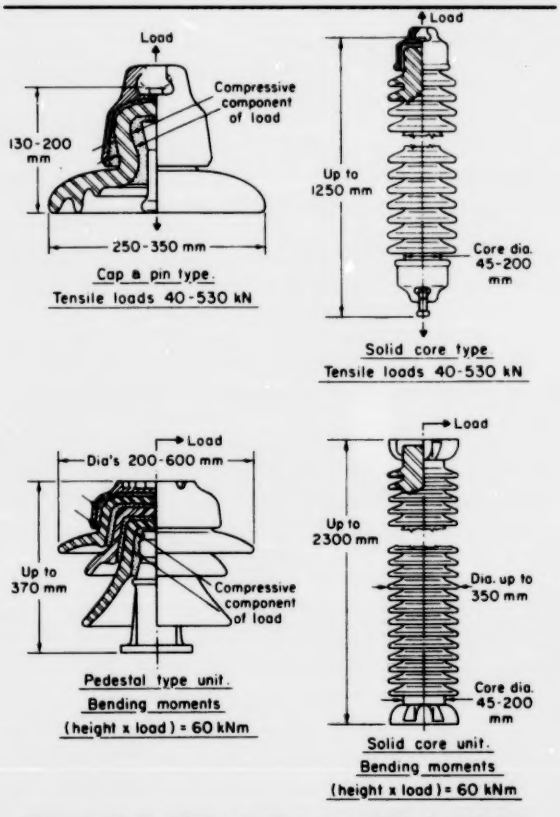

Figure 10.2 High tension porcelain insulators.

PRODUCT SPECIFICATIONS

The standards for high voltage insulators are usually set from the requirements of the utilities, these companies and their suppliers being the major users of high tension porcelain. Typical quality standards required for the ceramic in order to meet the final product standard are given in Table 10.1.

The electrical and mechanical specifications for high voltage insulators can be found in the ANSI, NEMA, CEMA and ASA standards: specifications are given for each type of insulator and their various class numbers.

RAW MATERIALS AND PROCESSES

The electrical insulating power of porcelain depends principally on the texture and density of the ceramic, and these in turn are controlled mainly by the chemical composition and the firing operation; however, every stage of insulator manufacture contributes to exploiting the electrical and mechanical properties of porcelain to its full advantage. The body formulation preparation is similar to that used for domestic porcelain and whiteware, the main ingredients being clay, feldspar and silica. Electrical porcelains tend to contain higher proportions of ball clay (as opposed to china clay) since whiteness is not a prerequisite for the body, and since ball clays generate higher workability and higher green strength. Typical formulations for electrical porcelain are given in Table 10.2.

In the 1970s, the science of electrical porcelain manufacture advanced considerably[1] and formulations have been developed which are far different from the conventional 'textbook' recipes. Microstructural variations to improve strength[9] have concentrated on developing the growth of acicular crystals of mullite within the matrix and has in-

TABLE 10.1 HI-VOLTAGE INSULATORS - QUALITY STANDARDS FOR CERAMIC BODY.(2)

Tensile Strength	5,000 psi
Compression Strength	60,000 psi
Modulus of Rupture (unglazed)	11,000 psi
Modulus of Rupture (glazed)	15,000 psi
Modulus of Elasticity	10,000,000 psi
Specific Gravity	2.4
Density	0.087 lbs./in.^{3}
Coefficient Linear Expansion	20 - 250°C - 5 x 10-^{6}/inch/°C
Dielectric up to 3/8"	250 kv/inch
Dielectric 1/2 - 1"	170 kv/inch
Dielectric Constant	6.3
Power Factor 1000υ	0.8
Hardness MOH	7.0
Moisture Absorption	0.0

TABLE 10.2 TYPICAL FORMULATIONS OF ELECTRIC PORCELAINS AND RELATED BODIES. (3)

Body		Body Formulation (wt. %)
Hard porcelain (fired under reducing conditions)	Clay	40–50
	Quartz	35–45
	Feldspar	15–20
Soft porcelain	China clays and Ball clays	50
	Quartz	25
	Feldspar	25
Aluminous porcelain	China clays and Ball clays	35–60
	Calcined alumina	20–40
	Feldspar	15–30
Steatite	Talc	70–85
	Clay and Feldspar	15–30
Steatite (low loss type)	Talc	75–85
	Clay	5–10
	$BaCO_3$	10–15
Cordierite	Clay	30–50
	Talc	40–50
	Al_2O_3	10–30
Electrical refractory body	Clay	60–80
	Grog	20–40

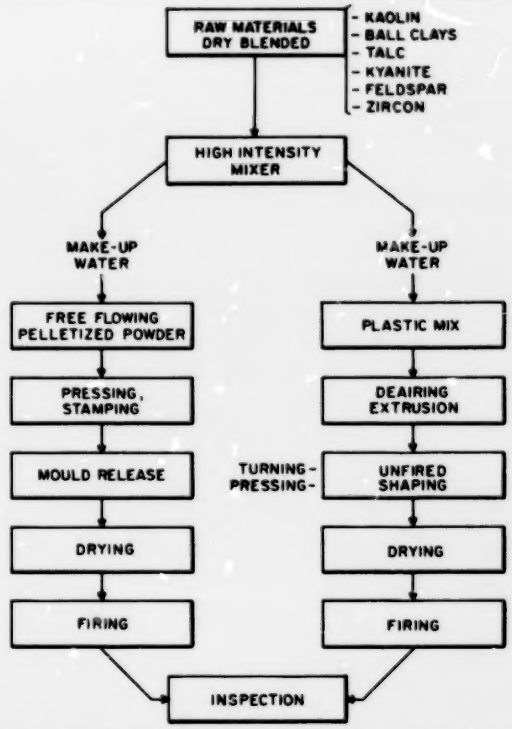

Figure 10.3 Process flow chart for semi–dry or plastic forming of electrical porcelain products.

cluded incorporation of minerals such as sillimanite and kyanite together with alumina at the expense of silica and feldspar minerals. Researchers have also studied the influence of mineralizers such as ZnO, TiO_2, Fe_2O_3, B_2O_3 and MnO_2 on the microstructure, strength and firing range of the porcelain.[5]

A porcelain with a high cristobalite content has been developed in Japan[7] which exhibits exceptionally high strength without the high cost generally associated with equivalent alumina containing formulations. The cristobalite crystallizes from highly siliceous bodies in the form of extremely fine particles. The whole emphasis of modern electrical porcelain manufacture has since shifted to *fine textured* and crystalline bodies which possess high strength and do not develop any excessive localized stresses in use.

The impact of the energy crisis in the mid–1970s and subsequent attempts to minimize energy consumption in ceramic manufacturing operations has resulted in major gains in not only energy but also microstructural engineering for electrical porcelain. The use of fine particle sized silica has been shown[8] to be beneficial in developing good mechanical strengths during fast–firing conditions, while the simultaneous use of nepheline syenite as a flux significantly minimizes microflaw development.

It is generally considered by the industry that potassium feldspars are the preferred fluxing ingredient due to beneficial electrical properties and increased firing range,[8] but its use is particularly determined by its availability and supplies of alternatives such as sodium feldspar and nepheline syenite.[10]

The replacement of flint by zircon has been found to greatly improve the tensile strength and dielectric constant of electrical porcelain.[4] However, the high cost of ground zircon has limited the commercial interest in zircon–porcelains at present.

Manufacturing (forming) processes (Figure 10.3) generally used by the electrical porcelain industry are:

- Low tension applications: semi–dry processing, extrusion, extrusion and turning, slip casting,
- High tension applications: extrusion and turning, slip casting, jolleying, warm pressing (of plastic mass).

HIGH VOLTAGE INSULATORS

CURRENT BUSINESS SCENARIO

High voltage ceramic insulators find application in generating stations, transmission lines, sub–stations and the distribution network.

The growth of this market is controlled by factors out of the control of producing companies, for example: transmission and generating station business is generated by construction of state or provincial systems (e.g. hydro–electric dams, nuclear power stations, thermal generating stations), and transmission to new or growing large industrial and/or residential areas. Similarly, the distribution aspects of the business are determined by urban area growth.

In the late 1970s and early 1980s these aspects of the Canadian and the U.S.A. marketplace stabilized. Power supplies became adequate and no new facilities and/or systems were being developed; consequently, the market declined rapidly.

Export opportunities to growing second and third world countries also deteriorated due to economic problems (ability to borrow funds and finance major capital projects) and competition from high quality Japanese products.

In the absence of new domestic capital power generating facilities and transmission/distribution business, the only opportunity remaining to a Canadian producer is the 'replacement' business which is relatively small. This is currently being serviced very efficiently by Japanese producers. It could, however, provide a viable opportunity to a *small* well organized (automated) domestic manufacturer. In this event, product quality would need to be high to replace current high quality Japanese products.

TECHNICAL DEVELOPMENTS REQUIRED

Technical improvements are still required by the user industry and may provide opportunities for future business developments. These are:

- improved resistance to radio interference voltage (e.g. by application of conducting glazes),
- improved cantilever strength (e.g. development of high strength, high alumina bodies),
- improved arc tracking resistance (e.g. development of a semi–conducting glaze), improved pollution resistance (e.g. use of semi–conducting glaze to dry wetted surfaces through heating effect).

ONTARIO MANUFACTURERS

HAMILTON PORCELAINS LIMITED

The Hamilton Porcelains Company was founded originally in 1852 and manufactured a wide range of household ceramic items; electrical porcelains became a specialty in the 1940s. Since that time, the company has diversified from simply manufacturing electrical porcelain to a wide variety of industrial custom refractory ceramic components (up to 1000 different items), although the core of its market is still related to the electrical industry.

The company has a strong commitment to research and development and technical assistance to its customers. These two items are cited as key ingredients to the company's current success.

At this time, 80 percent of the company's products are exported to markets in the U.S.A., Japan, Europe and Latin America.

Process Technology

The process technology applied by Hamilton Porcelains is essentially a dry pressing process. Ceramic formulations are mixed dry in an Eirich high intensity mixer, water is then added to produce a controlled, moist, free–flowing granular powder (up to 18 percent water) which is then compression moulded. A high degree of tolerance and complexity is usually achieved in the pressed ware by application of good die–design and a firm understanding of the raw material and unfired product properties.

Products are fired in either a tunnel kiln (to cone 11) or a "top–hat" periodic kiln (to cone 16).

Raw Materials

All of the products manufactured by Hamilton Porcelains contain some clay minerals, ranging from a low of 10 percent in non–porcelain products (where it is essentially used as a binder) to a high of 50 percent where it is used as an integral part of the porcelain body chemistry.

Kaolin and ball clay are imported from the U.S.A., mainly from Kentucky and Tennessee. Three types of talc are used, all are imported; they include a chloritic talc from California which is high in alumina content, a New York talc and a French talc. (Canadian talcs are considered to be unsuitable for use.) Kyanite, mullite and pyrophyllite are imported for use in specialty refractory products. Bentonite is imported from Wyoming for use as a binder. Potassium feldspar is imported from Custer in South Dakota for use as a flux. Zircon flour and zircon sand are imported from the U.S.A.

Nepheline syenite from Ontario is used as the major fluxing ingredient in porcelain formulations, the presence of sodium ions is not seen as a major problem for electrical applications. Pecan nut shell flour is imported from the U.S.A. as a pressing aid. All materials are received in bags and palletized for ease of materials handling and batch formulation.

Products

Major electrical products manufactured by the company are:

Zircon Ceramics: Arc chutes for use in high voltage circuit breakers and contractors, engineered in the range of 1,000 to 15,000 volts and 100 to 1,000 m.v.a. They exhibit properties such as: excellent arc interruption ability, high electrical impact resistance, good thermal conductivity, low electrical losses, high hardness, erosion resistance and thermal shock resistance.

Electrical Porcelain: Appliance parts, neon insulators, various electrical insulators, farm fence insulators. These may be glazed or unglazed.

SMITH & STONE LIMITED

Smith & Stone Limited currently manufacture thermoset, thermoplastic and porcelain ceramic insulators together with a range of household (sanitaryware) and refractory ceramic products. The electrical porcelain portion of the combined product line is for low tension insulator applications.

Process Technology

Essentially the process technology applied by Smith & Stone is to dry mix in an Eirich high intensity mixer and then add water to provide a suitable feed for a de-airing extrusion machine. The extruded products are subsequently 'turned' to produce the desired shape prior to drying and firing. In addition, a limited number of products are dry pressed from a granular product also produced in the Eirich mixer.

Dried products are fired in either a gas fired Swindell Dressler Tunnel kiln or a gas fired periodic kiln to cone 11/12. Approximately 50 percent of the product line is glazed.

Raw Materials

All of the products manufactured by Smith & Stone are clay based "porcelain" type bodies.

Kaolin and ball clays are imported from the U.S.A. Pyrophyllite is imported from the U.S.A. Silica is obtained from St. Canute in Quebec. Nepheline syenite from Ontario is used as a fluxing ingredient.

ELECTRO PORCELAIN COMPANY LTD.

Electro Porcelain Company Ltd. manufacture a range of low voltage insulating products for the electrical appliance and lamp industry, together with custom switch gear and refractory industrial products. The total production amounts to about 2700 kg/week.

Process Technology

The Company's manufacturing process is based on dry pressing and subsequent tunnel kiln firing (2 kilns). Raw materials are dry mixed in a Muller type mixer and subsequently wetted to produce a granular 'pressing' mix. All items are fired in a gas fired tunnel kiln at cone 11 after drying; both glazed and unglazed products are manufactured.

Raw Materials

All of the products are clay based porcelain bodies.

Kaolin clays are imported from Georgia. Ball clays are imported from Kentucky and Tennessee. Feldspar is imported from Connecticut. Nepheline syenite from Ontario is currently being used as a partial replacement for the U.S. feldspar. Talc is imported from Montana and New York (Canadian talcs evaluated to date have been found to be unsatisfactory). Silica is obtained in Ontario. In addition to the above, a small amount of pyrophyllite is used.

All raw materials are received in bags to aid materials handling and batch formulation.

NEW TECHNOLOGY

The electrical performance of ceramic materials is governed by the microstructure and surface condition (presence of defects, etc.). New high technology ceramics for application in electrical and electronic systems are being developed with an 'engineered' microstructure containing controlled dopants and impurities to produce the desired properties. Although these new ceramics are far removed from the traditional electrical porcelain products, it seems likely that some technology transfer could occur to improve performance. The recent rapid rise in the quality of Japanese products has also been reflected by the rapid developments of their high technology 'fine' ceramics.

There would certainly appear to be significant opportunity to develop improved glazed products for high voltage applications. The effects of pollu-

tion and water on flashover might be minimized with the use of suitable semi-conducting glazes.

Finally, vacuum circuit breakers are emerging as a significant alternative to conventional air magnetic circuit breakers. This will require a technology and/or product change for suppliers.

APPENDIX — ELECTRICAL PORCELAIN MANUFACTURERS IN ONTARIO (1986)

1. Hamilton Porcelains Ltd.
   25 Campbell Street
   Brantford, Ontario
   N3T 5N9
   (519) 753-2615
2. Smith and Stone Ltd.
   2 Glen Road
   Georgetown, Ontario
   L7J 2P4
   (416) 457-6000
3. Electro Porcelain Co. Ltd.
   173 Roger Street
   P.O. Box 400, Station K-W
   Waterloo, Ontario
   N2J 4A9
   (519) 576-2555

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Chapter 11 — Refractories

INTRODUCTION

In general terms, the world refractory industry has been in decline during recent years, and although 1984 showed some improvements,[5] the increased production took place in third world countries; the North American market continued to decrease.[9] The reasons for the decline are many, but the principal ones are:

i. the decline of the steel industry (approximately 60 percent of all refractories consumed in the world are used to make steel);

ii. changing technology (particularly in steelmaking processes where continuous casting is displacing ingot casting);

iii. the energy crisis of the mid-1970s;

iv. the economic recession of the early 1980s;

v. major changes in materials use patterns in consumer industries.

The clay refractories industry of Ontario has followed this general trend experienced by the North American market.

In the late 1960s or early 1970s, the principal refractory product was brick or other preformed shapes, such as arches, wedges, keys, and jambs. These products were dry pressed on mechanical or hydraulic presses and fired. These products have since been supplanted by what are often termed *unshaped, monolithic or plastic* refractories as the major component of the clay based refractory industry. This class of refractories, the formulations for which are highly proprietary and closely guarded, include refractory mortars, castables, mouldables, ramming mixes and gunning mixes. In addition, one company manufactures an insulating refractory aluminosilicate ceramic fibre which it preforms into a line of desired refractory shapes.

The following companies have been identified as active in the production (Figure 11.1) of this range of products. A list of addresses is given in the appendix at the end of the chapter.

- A. P. Green of Weston and Acton
- Continental Refractories of Oakville
- C. E. Refractories of Welland
- Babcock & Wilcox of Burlington
- Plibrico of Burlington
- North American Refractories of Caledonia
- BMI Refractories of Smithville
- Frontier Refractories of Grimsby
- General Refractories of Smithville.

Most of the above are branch plants or Canadian divisions of U.S. corporations and rely on the parent companies for supply of raw materials from captive sources. Two of the above are small independent Canadian companies.

In comparison to the refractory brick market, the monolithic refractory market is less well defined, relatively small but of high value. Major markets served include:

- the steel industry (refractory linings),
- the glass industry (glass tanks),
- the cement industry (rotary kiln refractory linings).

These markets are highly competitive and shrinking in size. Factors which are seen to contribute to this decline are:

- manufacturing technology changes in steel manufacture,
- lack of new installations under construction (excess capacity),
- increased quality and life of current refractory products,
- reduced maintenance of installations.

The predominant factors contributing to the decline of the refractories industry are undoubtedly the major changes which have occurred in the steel industry. The accelerated move to continuous casting technology observed in North America is being driven by the significant economic benefits which accrue from this process. It is not anticipated that this technology will significantly increase the size of the steel industry, however it will displace the less efficient ingot casting technology. It should be noted that in Japan, approximately 90 percent of all steel produced is generated by continuous casting, while in Europe 70 percent of steel is produced by this technique; in North America 45 to 50 percent is continuously cast. At the present time, Canada typifies the rest of North America with approximately 40 percent of its production being generated by continuous casting. However, new developments within the country's major producers will raise this level to approximately 80–85 percent by 1987.

Coupled with the conversion to continuous casting technology is an accompanying demand for higher purity steel and improved refractory service (or performance). Refractory manufacturers are,

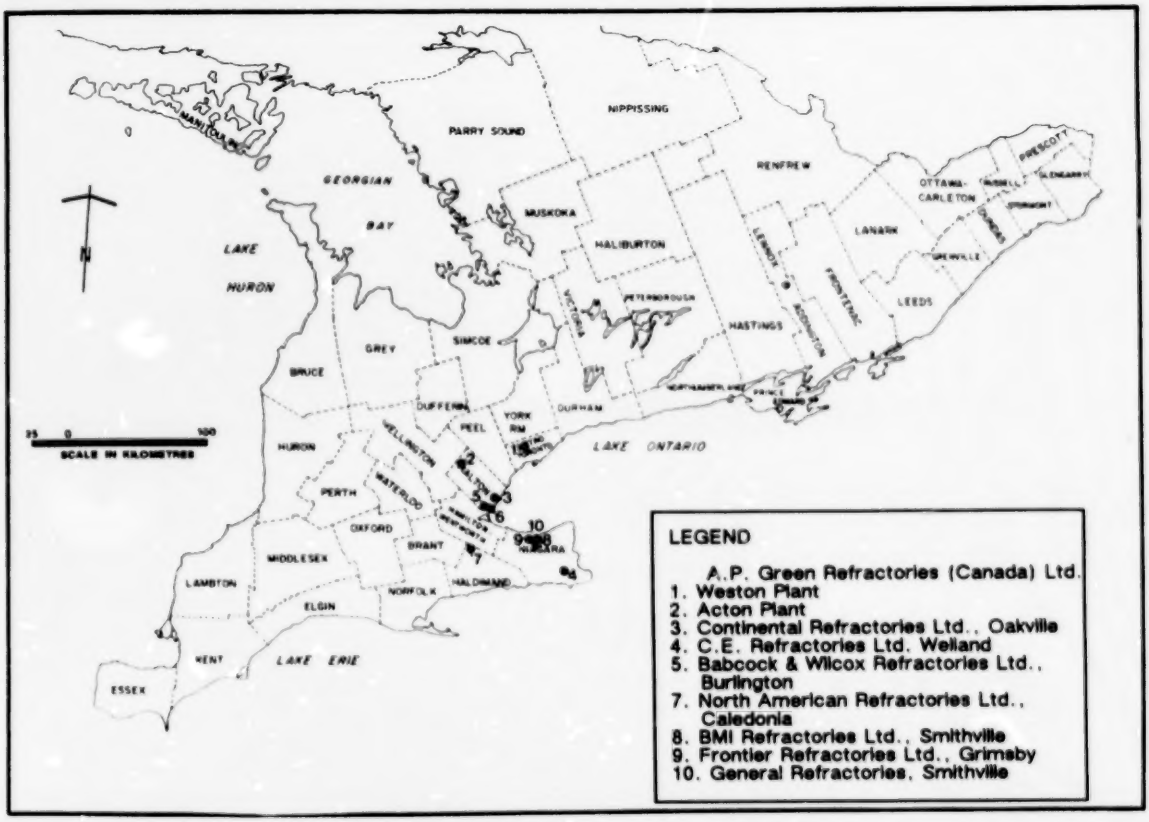

Figure 11.1 Clay refractory manufacturers in Ontario.

therefore, required to supply products that last longer, yield cleaner (purer) steels and cost less per unit of steel produced. This in turn requires improved consistency and the development of new improved materials to meet the new demands and the changes in use patterns. The net result of these requirements is that the total tonnage of refractories used by the steel industry has decreased as higher performance (longer lasting) materials have displaced lower quality materials used in the past.

It has been noted[11] that with very few exceptions, the fireclay and medium alumina refractories are being displaced; while high–alumina, chrome–alumina, magnesia and zirconia refractories are already finding wide acceptance. It is considered that refractory manufacturers need to utilize these materials and combinations thereof in conjunction with minor additives and new and/or improved bonding agents to yield refractories with improved wear resistance strength and thermal shock resistance. The objective of such blends should not necessarily be the production of lower cost refractories but higher purity steels and lower refractory cost per unit of steel produced.

PRODUCT DEFINITIONS AND PROCESS TECHNOLOGY

CLASSIFICATION OF REFRACTORIES

The classification of refractories can be approached in several ways, Table 11.1 provides a guide to refractory compounds and the raw materials from which they are made. Probably the most common classification system is into 'acid' and 'basic' products. The acid refractories are considered to be the silica refractories and those in the alumina–silica group with a high silica content, whereas magnesia, dolomite, chromite and forsterite are classified as basic refractories. The high alumina content refractories from the alumina–silica group are considered neutral.

Table 11.1 indicates that clay based refractories fit into the alumina–silica grouping.

TABLE 11.1 REFRACTORY COMPOUNDS. (3)

Refractory Type	Sub-section	Raw Material(s)
Silica SiO_2	Regular	
	Super-duty	Ganister, silica sand
	Insulating	Perlite, dolomite
Alumina-silica Al_2O_3 & SiO_2	Low alumina (<45% Al_2O_3)	Flint and plastic fireclays
	High alumina (>45% Al_2O_3)	Kaolin Bauxite clays Kyanite, sillmanite and andalusite Synthetic mullite Diaspore Bauxite (calcined)
Alumina Al_2O_3	-	Bayer-process alumina
Magnesia MgO	-	Magnesite or seawater magnesia
Magnesia-lime MgO & CaO	-	Dolomite (sometimes enriched with magnesia)
Magnesia-chromite	Chrome/magnesia (<50% MgO)	
	Magnesia/chrome (>50% MgO)	
Magnesia-silica MgO & SiO_2	Forsterite	Olivine
Chromite $FeCr_2O_4$	-	Chromite (chrome ore)
Zirconium compounds	Zirconia (ZrO_2)	Zircon sand
	Zircon ($ZrSiO_4$)	
Carbon C	-	Graphite (natural or synthetic) or coke
Silicon carbide SiC	-	Silica and petroleum coke

REFRACTORY BRICKS

Refractory bricks can be manufactured by all of the standard forming processes of moulding, extrusion and pressing. The Canadian experience has been traditionally one of preparing formulations in batchs using muller mixers and blade type mixers and subsequently pressing the desired shapes using either mechanical or hydraulic presses.

Pressing is a preferred method of fabrication because of the high tolerances and shape control required when products are laid up dry or in an interlocking mode. Several standard texts[2,8,14] are available which describe refractory brick technology in detail and should be referred to for further information.

REFRACTORY FIBRE INSULATION

Refractory ceramic fibres became commercially available in the late 1960s and are employed essentially as a thermal insulator. Their development escalated with the energy crisis of the mid-1970s such that their use has become standard practice in almost all refractory applications where insulation is required.

The most common type of ceramic fibre are the aluminosilicate types derived from clays although some alumina and silica fibres are also available.

Fibres may be manufactured in a variety of ways and in all cases the processes are proprietary and highly guarded. However, most commercial fibres are produced by melting appropriate raw materials and then forming the fibre in one of two ways:[4]

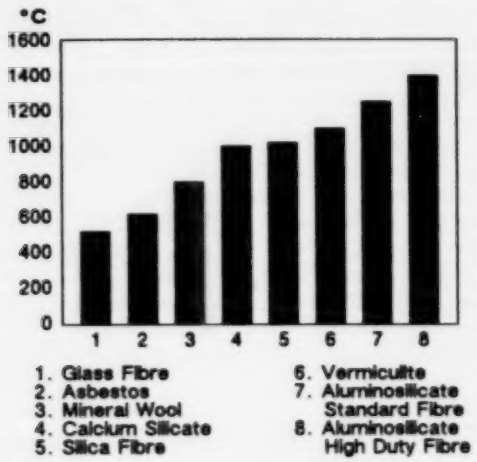

Figure 11.2 Maximum service temperatures of common insulating materials.

1. by pouring the melt in a stream and then blasting the stream with compressed air or other gases which breaks the stream into fine fibrous material; or
2. by pouring the melt onto the periphery of a spinning disc such that the liquid is thrown off at a tangent by centrifugal forces, causing fibres to form. This technique tends to form long silky fibres.

Other techniques are also available, the most noteworthy of which is that used for manufacturing alumina ("Saffil") fibres. This process involves the rapid drying of stabilized suspensions or hydrothermal solutions.

Figure 11.2 shows typical service temperatures of insulating refractory fibres compared to other common thermal insulating materials.

REFRACTORY MORTARS AND MONOLITHIC PRODUCTS

Refractory Mortars

Refractory mortars are used to bond individual bricks together into one solid unit. They also have the secondary functions of protecting the unexposed surfaces from attack by slag and providing resistance to infiltration by cold air or the outward flow of gases. There are two types of mortar – heat–setting and air–setting – but the basis of both is a fired refractory aggregate mixed with a plastic bonding clay. Heat–setting mortars are generally composed of nothing but aggregate and bonding clay and rely on firing in service to produce a ceramic bond. Air–setting mortars contain a special bonding agent, commonly sodium silicate (water glass), in addition to the aggregate and the plastic clay. The sodium silicate sets to form a strong chemical bond after drying at room temperature. A ceramic bond will form in the air–setting mortar at high temperatures, but the strength of the chemical bond is retained at intermediate temperatures. The initial cost of the air–setting mortar is greater than that of the heat–setting variety, but it is often more economical in service because of its properties.

The range of compositions for mortars varies considerably, but a primary requirement is that the mortar shall be compatible with the bricks. The refractory aggregate used is therefore usually close to the composition of the brick itself. The most common aggregates are fireclay, magnesite, chromite, alumina, silica and silicon carbide. Similar formulations are often used as coatings to improve resistance to abrasion and slag erosion.

Monolithics

A monolithic structure, by definition, is one which has no joints, and the field of monolithic refractories comprises virtually all refractories except bricks and mortars. These bulk refractory materials are applied to the furnace in a number of different ways but are best classified in the four groups – castables, mouldables, ramming mixes and gunning mixes. They were originally developed for the maintenance of furnaces but are now widely used as whole furnace linings.

Castables are in essence high–temperature concretes and are made from graded refractory aggregates bonded with hydraulic setting cements. They are supplied in a dry condition, and only water need be added for installation. Some form of mould or shuttering is put into position, the wet mix is cast, and tamping or mechanical vibration is employed to obtain optimum density. Alternatively, a castable may be 'gunned' into position pneumatically, or built up in stages by simple trowelling. Like ordinary building concrete made from portland cement, no heat is required to develop the strength, and the concrete sets in air to form a strong hydraulic bond. The cement used in refractory castables is a calcium aluminate type. The aggregate is high–burned fireclay or kaolin, and for insulating castables a lightweight material such as diatomite, perlite or vermiculite is often used.

Mouldables (or plastic refractories) consist of fired and graded refractory aggregates which have been blended with plastic clays and mixed with water to the desired consistency. This leaves them in a stiff, plastic condition which allows them to be

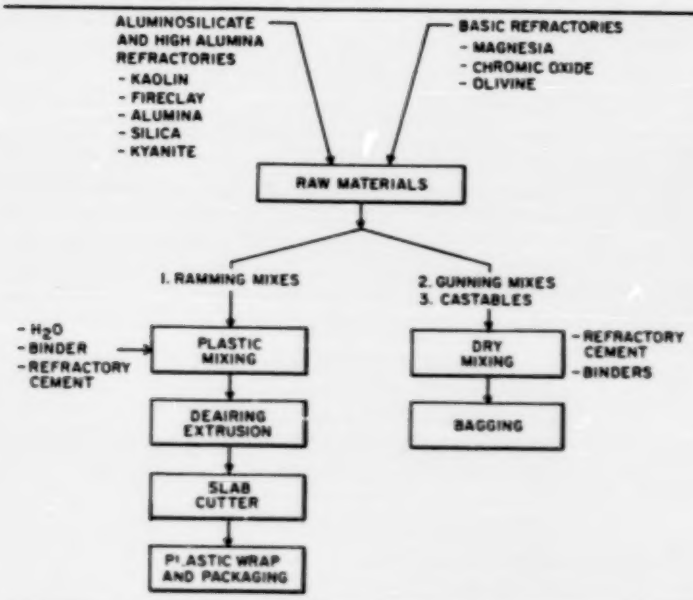

Figure 11.3 Process flow chart for the preparation of specialty refractories.

positioned in a furnace and rammed into place, either by hand or with a pneumatic hammer. When in position the material is fired to form a ceramic bond by the furnace itself. A variety of aggregate materials may be used including high and low alumina clays and chrome ore. The plastic bonding agent is nearly always a carefully selected plastic clay, but small amounts of phosphate are sometimes added to high-alumina aggregate.

Ramming mixes are very similar to mouldables except that they contain little or no bonding material. They are based on ground and sized aggregate of varying compositions including silica, fireclay, high-alumina material, magnesite, chromite, silicon carbide and zircon. They are pounded into place by mechanical means and fired in situ by the furnace itself.

Gunning mixes may be drawn from any of the three preceding categories, but they are generally nearest to castables. The basic difference is that the grading of the aggregate and the moisture content are altered to make them suitable for gun application. The mix is sprayed on to the desired surface by compressed air through a hose. Water is added either in the chamber of the gun or at the nozzle, but the latter is generally preferred as it gives more control. Once applied the mix is allowed to set in the normal way before firing. The method is extremely rapid and, because of improved gunning techniques, has been the fastest area of growth in the refractories industry.

One thing that all monolithic refractories have in common is that some form of *anchoring* is usually necessary to ensure that the material sticks firmly to the surface. The anchors may be refractory brick shapes or heat-resisting alloy steel supports, fixed to the surface at intervals, but they must be strong enough to hold the refractory firmly and be flexible enough to allow it some movement under thermal stress.

The preparation techniques (Figure 11.3) for each of the above are simple ceramic batch mixing procedures using muller mixers, pan mixers and blade mixers in wet or dry form. Materials are usually packaged in 50 pound (23 kg) pails or bags.

The batching of the formulation is of course necessarily important and care must be taken[8] in selecting the size distribution of aggregate components if optimum property development is to be attained.

DEVELOPING TECHNOLOGY

It is reported[12] that trends are developing away from water based systems for monolithic refractories. It is well known that control of moisture content, curing temperature and ambient outside temperatures when preparing castables are major factors in the final success of the product. Also many, if not all, are sensitive to dry-out procedures and heating rates. This is critical for industries such as the steel industry where down-time needs to be minimized and rapid heating rates are desired.

Japanese research[7] is currently aimed at developing high strength castable products which can rival standard 'shaped' products and 'flame–gunning'[13] (or flame spraying) of gunning mixes for improved rapid repair of refractory installations.

Recycling of refractory in the form of aggregate for monolithic refractory formulations is growing in interest;[10] all of the companies use some aggregate from this source and, one Canadian raw materials supply company[1] has initiated a business to supply crushed and graded material as a standard raw material to monolithic manufacturers.

ONTARIO OPERATIONS

The high degree of competition in a shrinking market has resulted in much caution on the part of the producers for disclosing information on formulations and raw materials used.

PLIBRICO COMPANY

The Plibrico Company of Burlington has been operating in Canada for more than 50 years. The company is a subsidiary of the Plibrico Company of Chicago, U.S.A. The company's product line includes monolithic ceramics of which approximately 10 percent are formed by pressing. The balance of the production is in plastic mixes, castables and mortars. All products are either aluminosilicate or high alumina refractory grades.

The company serves the following markets:

- steel industry,
- non–ferrous metals industry,
- petrochemical industry,
- mineral processing.

Products are sold only in Canada with no U.S. exports; some materials are exported to offshore countries but generally only for Government aided projects where Canadian content is mandatory.

Raw Materials

Fireclays and ball clays are imported from the U.S.A. in bulk shipments. Refractory bauxites, alumina and binding agents are obtained from Canadian sources.

Canadian raw materials would be considered for application as long as cost competitiveness could be maintained.

Processing Technology

Bulk raw materials are dried, crushed and blended using standard techniques. Castable products are subsequently bagged. Plastic mixes are extruded before packaging while pressed products are dry pressed by mechanical hydraulic techniques.

Two shuttle periodic kilns are retained for firing brick products and specialty shapes. (Approximately 10 percent of total production is fired.)

NORTH AMERICAN REFRACTORIES

North American Refractories Ltd. is a subsidiary of The Allied Corporation, and has been operating in Caledonia for approximately 20 years. The company employs about 30 people, of which approximately one–half are directly involved in production.

The company manufactures high alumina, basic and magnesite refractory products, high heat mortars, castables, ramming and gunning mixes. Most of the products are designed for quick installation and repair work. Refractory bricks are not included in the company's product line.

Products are marketed only in Canada and primarily to steel plants although the following additional markets are also served:

- non–ferrous metals industry,
- minerals processing industry,
- cement industry,
- foundry industry,
- glass industry.

Process Technology

All products are batch formulated. Raw materials are blended and binders such as calcium aluminate and phosphoric acid added. Raw materials are mixed in an Eirich mixer. Dry products are subsequently bagged while plastic mixes are fed to an extruder/shredder and wire cut before packaging.

None of the products are fired. Total production is between 3600 and 4500 tonnes per year of which about half is clay mixes and half is high alumina mixes.

Raw Materials

A wide variety of clays are imported from the U.S.A. including kaolin, ball clay and fireclays. The clays are selected on the basis of their alumina contents and iron impurities. Approximately 1800–2300 tonnes of clay are imported each year.

Refractory bauxites and fireclay together with magnesite are purchased from captive sources or through the parent company.

A. P. GREEN REFRACTORIES

A. P. Green Refractories (Canada) Ltd. is a subsidiary of a major U.S. refractories company; the Cana-

dian company is a division of Canadian Gypsum Company which in turn is owned by U.S. Gypsum. The company has been marketing refractories in Canada for over 50 years, and manufacturing products locally since the 1940s. The company operates two plants in Ontario, one in Weston and the other in Acton.

The Weston plant manufactures specialty refractory products, castables, plastics and mortars, mainly in the aluminosilicate and high alumina refractory groups. Products range from low duty to high duty and super duty refractories. (Super duty refractories are those containing up to 95 percent Al_2O_3.) Insulating castables containing vermiculite, perlite and insulating grog are also included in the product line, as are some alumina–chrome mixes.

The Acton plant produces high heat duty refractory brick as its main product together with fireclay crucibles for assaying purposes.

The company's major market is the steel industry to which 40–60 percent of total production is dedicated, other markets include:

- foundry industry,
- non–ferrous metals industry,
- petrochemical industry,
- ceramic kiln linings,
- heavy clay industry.

Most of the market is in Ontario, although some products are exported to the U.S.A.

Raw Materials

High alumina clays are imported from the U.S.A. (some from captive sources). Refractory bauxite clays are imported from South America and China. Ball clays are imported from Kentucky and Tennessee. Fireclays are imported from captive sources in Mexico and Missouri and are also purchased in Saskatchewan. Alumina is purchased from both Canadian and U.S. sources. Silica is imported from Illinois. Chrome is imported from the U.S.A. Vermiculite is purchased in Canada. Perlite is purchased in Canada.

At the Weston plant 5400–7300 tonnes per year of clay are used as raw material.

Total production is 13,600–16,300 tonnes of refractories per year.

At the Acton plant total clay consumption is 2700 tonnes per year; products are 100 percent clay based.

Process Technology

All materials are received preground to required specifications, some of the clay products are received in bulk form, others are purchased in bags.

Raw material mixing is achieved in a Clearfill wet mixer or a Simpson dry mixer. Plastic products are extruded in 25 kg blocks or packaged, dry mixed products are simply bagged.

Bricks are produced by dry mixing as above and subsequent dry pressing using mechanical and hydraulic presses.

CONTINENTAL REFRACTORIES

Continental Refractories Ltd.'s Oakville plant was formerly owned by the Kaiser Refractories Company. In 1984, the Kaiser company sold its refractory operations to its employees and a new company, National Refractories, was formed. In January 1985, the Continental Refractories Company was created for the Canadian operation as a wholly owned subsidiary of National Refractories.

The company manufactures basic refractory specialties and clay alumina specialties, (monolithics) for the Canadian market. Industries served include:

- steel industry,
- non–ferrous metals industry,
- petrochemical industry,
- foundry industry,
- glass industry.

Refractory bricks were produced up until the late 1970s but production was discontinued when the economic downturn seriously reduced capital investment in new plants.

Raw Materials

Clays are imported from the U.S.A. from captive sources. Calcined clays are imported from the U.S.A. Refractory bauxites are imported from South America. Tabular and calcined alumina are purchased from Canadian and U.S. sources. Bonding agents are imported from the U.S.A. Grog (recycled refractory) is purchased from Canadian sources.

All raw materials are purchased in bags through the parent corporation; Canadian raw materials must be cost effective in order to receive preference over corporate buying policy.

Process Technology

Process technology at Continental Refractories is essentially one of mixing and packaging with a large

manual labour component. Mixing is achieved in Lancaster mixers for coarse grained dry products and in a Simpson mix–muller for fine grained wet products. Dry products are packaged in bags semi–automatically; wet products are packaged in 2–1/2 gallon (11 litre) pails.

BABCOCK & WILCOX REFRACTORIES

Babcock & Wilcox Refractories Ltd. of Burlington is a Canadian subsidiary of Babcock & Wilcox of New Orleans, U.S.A., which in turn is owned by McDermott Inc. of New Orleans. The Burlington plant has operated since 1965, initially under the name of Standard Refractories.

The company's major product is a high temperature ceramic fibre insulation (Kaowool) in the form of bulk fibre and vacuum–formed shapes. Secondary products are refractory castables, mortars and plastic mixes. Products are marketed only in Canada.

Ceramic fibre products find service in the following industries:

- steel industry,
- aluminum industry,
- commercial kiln and furnace installations,
- glass industry,
- commercial thermal insulation.

Raw Materials

China clays are imported from Georgia (captive source). Ball clays are imported from the Carolinas. Calcined kaolin is imported from Georgia. Fireclays are imported from the U.S.A. Refractory bauxites are imported from South America. Kyanite is imported from the U.S.A. Alumina is purchased in Canada and the U.S.A.

Total clay imports are 3600–4500 tonnes per year.

Manufacturing Technology

Ceramic Fibre Products

The manufacturing process for "kaowool" is a proprietary process and no information on the process is available.

Monolithic Products

The manufacturing process for monolithic products is simply one of weight batching, mixing and packaging. Plastic products are mixed in a muller mixer, extruded into blocks, wire cut to size and packaged, dry mixed products are simply bagged. Mortar mixes are supplied wet in drums of up to 340 kg batches.

FRONTIER REFRACTORIES

Frontier Refractories Ltd. is a manufacturer of refractory removing and gunning mixes. The majority of the products are formulated for use in iron making cast house operations. The company serves the domestic market with only a small amount exported to the United States.

Frontier imports clay from the United States, and uses a milled and air dried ball clay in the mixes. Approximately 45 tonnes of clay are used in one year. The process specifics for the preparation of the mixes are proprietary information and were not released by the company.

BMI REFRACTORIES

BMI Refractories Ltd. produces monolithic specialty refractories, including ramming, gunning and tamping mixes. The company serves a domestic market only.

The company basically employs a batching–mixing–packaging operation. They have three process lines; a dry mixing process for the cement castables, a wet mixing line for the water–based ramming mixes, and a third line for the tar bonded specialties.

BMI import their clay from the U.S.A. and use predominantly ball clays with a small amount of a crude fireclay. They estimate a consumption rate of approximately 900 tonnes of clay per year.

GENERAL REFRACTORIES

General Refractories Ltd. is currently expanding its product line to include alumina–based specialty refractories. The company plans to produce gunning, ramming and plastic mixes. The clay will be imported from the U.S.A. No data are available, however, on estimated consumptions.

C. E. REFRACTORIES

C. E. Refractories Ltd. produces gunning and ramming mixes and castable refractories. The company imports clay from the U.S.A. Mainly ball clay is used in the mixes; a very small amount of fireclay is also used. Roughly 450 tonnes of clay is used per year.

The process at C. E. Refractories is basically batching–mixing–packaging. The company serves predominantly a domestic market with about 95 percent of the sales in Canada.

PRODUCT AND MARKET TREND OBSERVATIONS

By far the majority of monolithic refractories find application in the steel industry. Recent technological changes in that industry such as direct casting and the elimination of casting pits together with improved performance of modern products, have given rise to a decrease in the market for monolithic products. Increased competition in a shrinking market requires development of new and improved products to ensure and stabilize market share.

Among technical developments which are being considered, is the elimination of inorganic binders and their replacement with organic systems; lower water and cement contents are considered to improve durability and slag resistance.

Another technology which provides an opportunity for development is the design and application of refractory coatings which are more compatible with the slag chemistry. Ideally the adhesion of the slag to the coating and the subsequent creation of an interface or boundary layer could set up a barrier against corrosion and erosion, and again improve the life of the refractory.

APPENDIX — PRODUCERS OF REFRACTORIES IN ONTARIO (1986)

1. A. P. Green Refractories (Canada) Ltd.
   234 Rosemount Avenue
   Weston, Ontario
   M9N 3C4
   (416) 241-5241
2. A. P. Green Refractories (Canada) Ltd.
   159 Perth Street
   Acton, Ontario
   L7J 1C9
   (519) 853-0840
3. Continental Refractories Ltd.
   P.O. Box 488
   Bronte Road
   Oakville, Ontario
   L6J 5A8
   (416) 827-4155
4. C. E. Refractories Ltd.
   Prince Charles Drive
   Welland, Ontario
   L3B 5P4
   (416) 732-4441
5. General Refractories
   Smithville, Ontario
   L0R 2A0
   (416) 957-3311
6. Babcock & Wilcox Refractories Ltd.
   1185 Walkers Line N.
   Burlington, Ontario
   L7M 1L1
   (416) 335-3414
7. Plibrico Co.
   P.O. Box 4355
   Fairview Street
   Burlington, Ontario
   L7R 3Y7
   (416) 639-8660
8. North American Refractories Ltd.
   201 Sterling Street West
   P.O. Box 40
   Caledonia, Ontario
   N0A 1A0
   (416) 765-4404
9. BMI Refractories Ltd.
   P.O. Box 490
   Industrial Park Road
   Smithville, Ontario
   L0R 2A0
   (416) 957-2301
10. Frontier Refractories Ltd.
    P.O. Box 427
    Durham Road
    Grimsby, Ontario
    L3M 4H8
    (416) 945-1998

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Chapter 12 — Mineral Wool

INTRODUCTION

Mineral wool is a fibrous, glassy material used as a low–cost insulating material. It is produced in a two–stage process consisting of a raw material melting step, followed by a fibrization step. In Ontario the raw material used is blast furnace slag. However, argillaceous dolostones, calcareous shales, basalt and other metallurgical slags can also be used. In most cases, the addition of small amounts of silica and/or nepheline syenite to the raw material can improve the quality of the fibre.

First recorded production of mineral wool was in Wales around the middle of the last century. In the U.S.A., wool was first produced from slag in 1870 at Greenfield, New Jersey. However, production was not substantial until 1897 when a plant at Alexandria, Indiana, commenced operations using siliceous dolostone from nearby deposits.[13,29] Slag wool was first made in Germany about 1870.

Early producers in Ontario included Canadian Johns–Manville Company Limited in Scarborough, Gypsum, Lime and Alabastine (Canada) Limited at Caledonia, and Spun Rock Wools Limited in Thorold, all of which have since closed. Currently there are four plants operating in Ontario, these being:

- Canadian Gypsum Company, Weston,
- Partek Insulations Limited, Sarnia,
- Roxul Company, Milton.

Ontario plants (Figure 12.1) produce about 100,000 tonnes of mineral wool annually, about half of which is exported to the U.S.A.

Mineral wool competes directly with fibreglass. It is superior to fibreglass in refractoriness and insulating properties, but lacks its good white colour, an

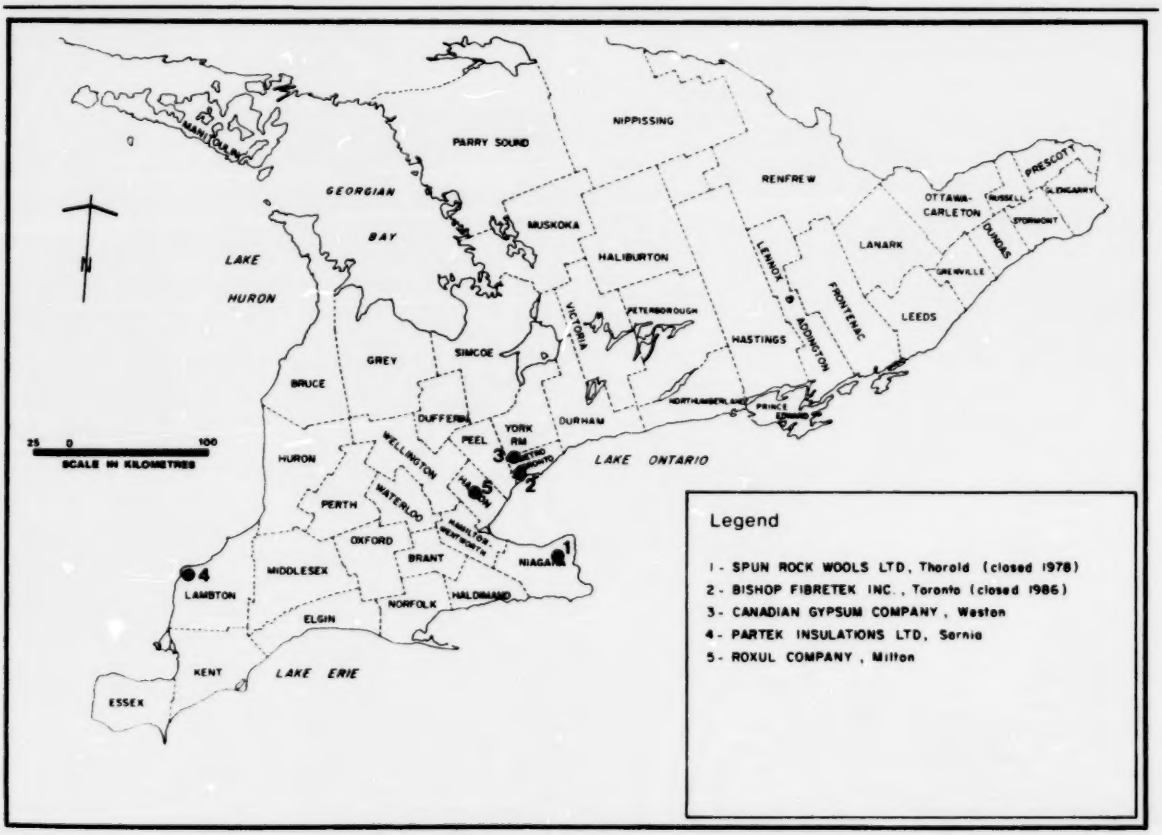


Figure 12.1 Mineral wool producers in Ontario.

appearance of purity and the ability for weaving into cloth. Mineral wool is marketed largely as loose insulation for pouring or blowing into residential attics and walls. Unlike fibreglass, mineral wool does not settle appreciably after installation. Hence, its installed thickness persists over time, whereas gradual loss of entrapped air in fibreglass can result in a thinner insulating blanket than originally installed.

Mineral wool can also be pressed with a binder into rigid batts and boards of any size, or rolled for pipe insulation. It is a major ingredient in fire resistant acoustical ceiling tiles, and finds special application as insulation in prefabricated chimneys and other high–temperature uses.

Other recent applications for mineral wool and mineral wool waste are as a thickener in drilling fluids and in horticulture. Experiments have been performed on growing various crops in mineral wool and on using mineral wool waste as a soil amendment. Mineral wool waste has also found application as a raw material in the manufacture of bricks.

RAW MATERIALS

Mineral wool can be made from a variety of naturally occurring rocks and minerals including shale, basalt, argillaceous dolostone, as well as most metallurgical slags (Photo 12.1). To all of these are usually added some silica, dolomite or nepheline syenite as necessary to achieve a batch composition in the range shown in Table 12.1. Such a chemical composition is known from empirical evidence and from phase diagrams, to produce a melt of the desired viscosity and a fibre of good quality.

Other raw materials recently investigated include asbestos mine and asbestos–cement tailings,[9,32] and cement kiln dust.[2] The addition of zirconium oxide for alkali resistance[14] and chromium oxide for corrosion resistance[7] have also been investigated.

Of the various techniques used for proportioning of the raw materials, two are in common practice: the use of phase equilibrium diagrams, and a consideration of the acid to base ratio. In the $CaO–MgO–Al_2O_3–SiO_2$ and the $CaO–MgO–Al_2O_3–SiO_2–Fe_2O_3–FeO$ systems, the relationship between viscosity, temperature and composition has been published.[23,27] Thus by choosing an operating temperature and a desired viscosity, a composition in terms of these oxides is indicated. Good wool usually results from viscosities between 6 and 12 poise (0.6–1.2 Pa.s) at temperatures between 1400 and 1450°C.[34]

Experiments on the viscosity–temperature relationship of various mixtures incorporating slag, quartz, trap rock, limestone and nepheline syenite waste have also been performed.[28] Finally, the use of density and surface tension as parameters in the manufacture of mineral wool has been investigated;[40] a model describing the relationship between batch composition and melt surface tension has been presented.

Photo 12.1 Mineral wool raw materials: (left to right) sandstone, slag, nepheline syenite. Photo courtesy of Roxul Company.

Lime, magnesia, alumina and silica are the predominant relevant oxides in the manufacture of mineral wool. Individually they all have melting temperatures higher than those obtained in cupola furnaces, however, when combined, they readily fuse at lower temperatures. Some mixes that give the lowest fusion temperatures (i.e. eutectics) are listed in Table 12.2. Raw materials used in the mineral wool batch are each rich in one or more of the four essential oxides.

Shale

Mineral wool can be made from mixtures of shale and dolomitic lime; it has also been produced commercially in Ontario from argillaceous dolostone. In 1933 there were 10 rock wool plants and 9 slag plants in the U.S.A.[16] The many sources of molten slags of various compositions have reduced the importance of natural sources.[17]

Laboratory testing has shown that fibre made from a mixture of 60 percent Georgian Bay Shale (formerly Dundas Shale) and 40 percent dolomitic lime is of good quality and whiteness but has lower tensile strength than slag fibre.[34] Similar tests using a blend of 76 percent Queenston Shale and 30 percent dolomitic lime produced a stronger fibre which, however, was still weaker than slag fibre.[34]

Most Ontario shales could be used in the manufacture of mineral wool, with suitable blending with dolomitic lime or dolomite.

Slag

Slags from the blast furnace smelting of iron are the most widely used raw material because of availability and cost. However, steel slag from the refining of iron to steel, and nickel or copper slags can also be used. Slag compositions are rarely ideal, and additions of silica or nepheline syenite are usually necessary to get the right melt viscosity. (Slag has been used in some instances without additives in several

TABLE 12.1 COMPOSITION OF MINERAL WOOL RAW MATERIALS.

	Desired Range	Hamilton Slag	Rochester Shale		Georgian Bay Shale	Queenston Shale
Reference	(15)	(34)	Thorold (13)	St. Davids (16)	(19)	(19)
SiO_2	24–32	38.21	24.28	25.33	55.66	51.28
Al_2O_3	8–12	8.21	11.16	9.50	15.30	13.90
Fe_2O_3	2–3	0.67	0.84	2.57	6.60	6.15
CaO	16–21	36.97	21.53	21.10	4.63	9.00
MgO	10–13	13.1	11.23	10.50	2.82	3.48
SO_3		1.5	1.24		0.78	0.26
LOI	26–29	0	29.10	27.73	9.22	11.08
Alkalis				2.56		
Total		98.7	99.38	99.29		

TABLE 12.2 MELTING POINTS OF THE MAIN MINERAL WOOL OXIDES AND SOME OF THEIR BINARY AND TERNARY EUTECTICS. (24)

	Melting Point (°C)	Mix Proportions (%) CaO	MgO	Al_2O_3	SiO_2
Oxides					
CaO	2570	100			
MgO	2800		100		
Al_2O_3	2040			100	
SiO_2	1728				100
Binary Eutectics					
$CaO–Al_2O_3$	1397	50.3		49.7	
$CaO–SiO_2$	1438	36.0			64.0
$MgO–SiO_2$	1547		35.0		65.0
$Al_2O_3–SiO_2$	1595			5.7	94.3
Ternary Eutectics					
$CaO–Al_2O_3–SiO_2$	1165	23.3		14.7	62.0
$MgO–Al_2O_3–SiO_2$	1347		20.3	18.3	61.4
$CaO–MgO–Al_2O_3$	1345	41.5	6.7	51.8	

plants in the U.S.A.[38]) Current Ontario practice favours the use of a combination of blast furnace slag and silica, which produces a wool of good quality and whiteness. Nepheline syenite can also be added to slag, alone or combined with silica.

Slags produced in the smelting of base metals tend to contain more iron than is desirable, resulting in darker coloured wool. Perhaps the most serious disadvantage in using slags is their sulphur content which, when oxidized and expelled in the flue gases, requires pollution control measures. A typical composition of blast furnace slag from Hamilton steel plants is given in Table 12.1. Slag has been the principal raw material for mineral wool in North America since World War II.[29]

Basalt

Rocks of gabbroic composition are being used in some plants in the U.S.A. as the principal raw material for mineral wool. Some commercial "basalt" fibres have reinforcing properties comparable to fibreglass, with greater refractoriness, better adhesion to epoxy resins and superior alkali resistance.[37]

Experiments with metabasalt from Havelock, Ontario, mixed with 30 percent Hamilton blast furnace slag have produced a good quality fibre of a greyish colour.[34]

Wollastonite

Wollastonite, calcium silicate, is used in Finland, finely ground with dolomite and coke, as a raw material for mineral wool. Its use without additives has also been reported.[24]

PROCESS TECHNOLOGY

The manufacture of mineral wool is essentially a two–stage process involving first the melting of the rock or slag batch, and secondly the conversion of the melt into fibre (Figure 12.2). A description of plant requirements for mineral wool manufacture,[1] as well as a census of U.S. manufacturers,[30] have been published.

Melting is generally accomplished in a cupola (Figure 12.3), a water–jacketed vertical steel furnace, unlined except for a refractory base. An evaluation of refractories for mineral wool furnaces has been published.[8] Combustion air and sometimes natural gas and oxygen are introduced near the base through a number of jets. The principal fuel is coke which is mixed with the other batch constituents and fed into the top of the cupola. The melt collects in a pool at the base and is drawn off continuously in a thin stream to the fibrizing unit. As melt is withdrawn, new charges of coke and slag or rock descend towards the melting zone. Temperature in the melting zone is maintained at about 1500°C. When using slag, small quantities of molten iron which sink to the bottom of the melt pool are periodically tapped off.

Cupolas in use today require raw material in lump form, generally coarser than 5 cm, to allow the flow of combustion gases through the material. Finer particulates may be entrained in the flue gases

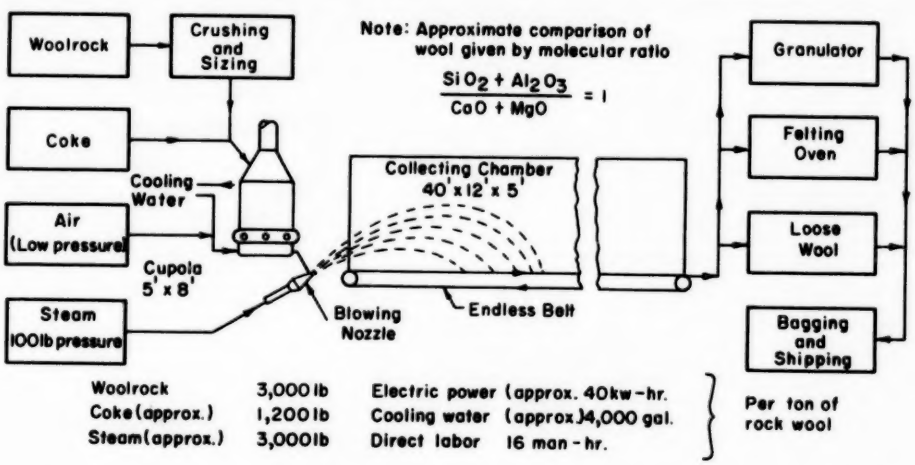


Figure 12.2 Schematic diagram of a mineral wool plant by the blowing method.[33]

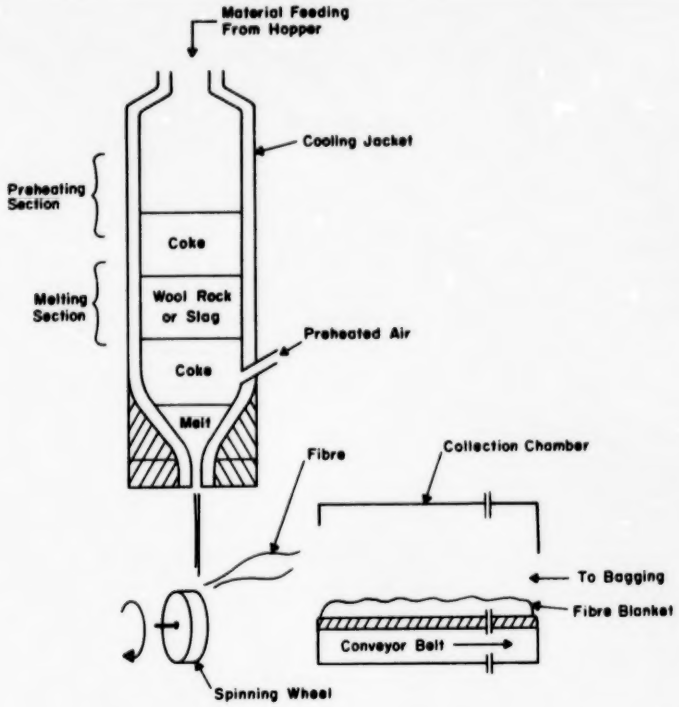


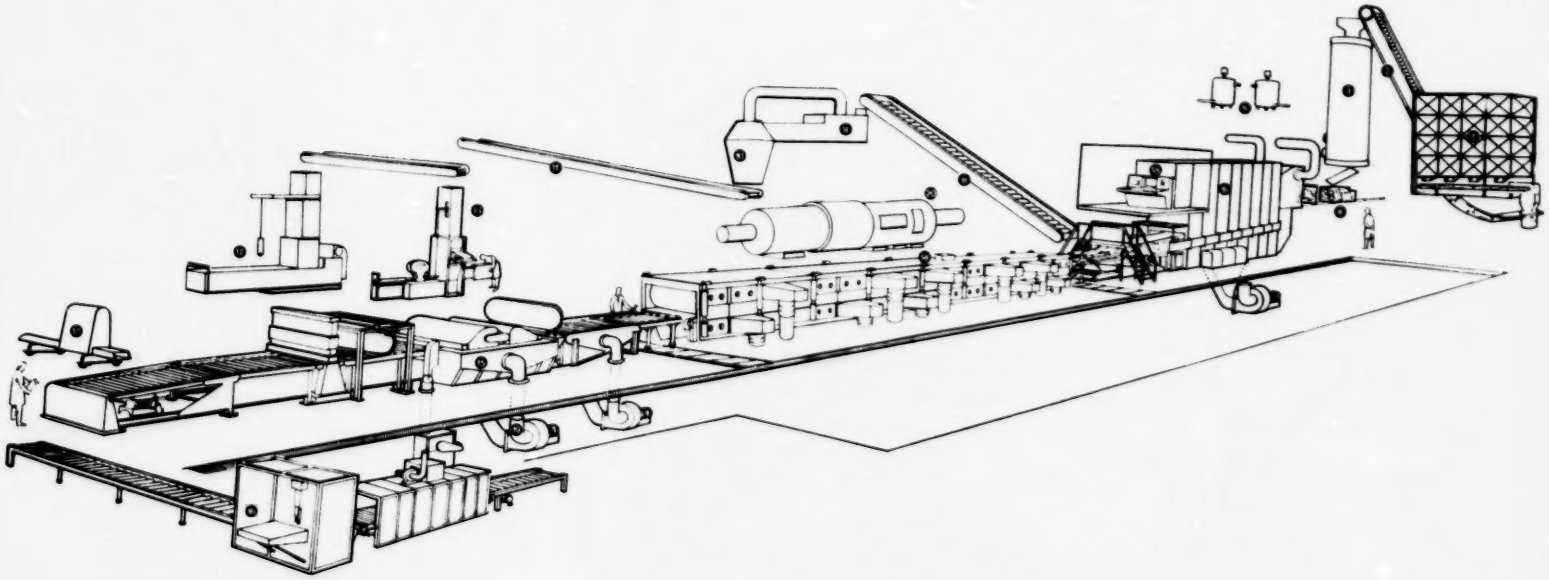
Figure 12.3 Schematic diagram of the mineral wool cupola furnace and spinning wheel.

causing both raw material loss and air pollution. Electric arc furnaces, in use elsewhere, have the advantage of being able to process finer raw materials without product loss. In the case of friable raw materials such as sandstone or shale this may be a significant advantage in terms of maximizing utilization of the resource. In isolated cases, reverbatory furnaces have been used in mineral wool production, but neither they nor electric arc furnaces are as fuel efficient as cupolas. There has been a steady stream of published articles and patents regarding mineral wool furnaces. Recent developments include use of gas electric combination furnaces,[10,35] oxygen injection in shaft furnaces,[18] conversion from a hot–blast cupola furnace to a cold–blast operation,[11] and heat recovery.[36] In addition, a unit for remelting mineral wool wastes has also been discussed.[31]

Fibrizing is accomplished in three of the Ontario plants by feeding a thin stream of melt into a vertical configuration of four spinning grooved wheels. The fourth plant uses a horizontal configuration. The stream is broken into beads which are flung from the spinning wheels; the velocity of the bead results in a long tail being formed, the tail giving the product its fibrous nature. Fibres can also be produced by directing a high pressure stream of air or steam against the melt droplets, a process which was used in the Caledonia plant before its closing. Steam at a pressure of nearly 0.7 MPa (100 psi) was directed against the stream of melt converting droplets to fibres. Spinning produces a longer fibre than the pressurized stream process.

Again, there have been many papers and patents regarding fibrization. Recent notable developments include an apparatus for intercepting partial fibres ejected from the difibrillation wheels[3] and regeneration of the working surface of the fibre spinning disc.[21,22]

In all cases the quality of the fibre is related mainly to the viscosity of the melt and, to a lesser extent, the thickness of the melt stream. A too viscous stream yields thicker, more brittle fibres, while a low viscosity stream yields short fibres with poor felting qualities. The viscosity also affects the production rate with lower viscosities yielding increased production. Viscosity is primarily controlled by chemical composition of the batch: the more silica, the higher the viscosity and thicker the fibre. The ideal is a fibre between 3 and 10 microns in diameter, and this requires careful proportioning of the batch plus close monitoring of the cupola melting zone and speed of the spinners. Methods for estimating fibre lengths by light scattering have recently been published.[5,6]



1. *Raw Material Storage*
2. *Charging Conveyor*
3. *Cupola Furnace*
4. *Spinners*
5. *Binder Preparation*
6. *Blowing Chamber*
7. *Cutting Equipment*
8. *Conveyor for Loose Wool*
9. *Cleaning System for Loose Wool*
10. *Cyclone for Loose Wool*
11. *Conveyor for Loose Wool*
12. *Baler for Large Packages of Loose Wool*
13. *Bagger for Loose Wool*
14. *Conveyor Table for Rigid Boards & Batts*
15. *Cutting Stations for Boards & Batts*
16. *Shrink Wrap Packaging*
17. *Friction-Fit Batt Packager*
18. *Main Control Panel*
19. *Exhaust Purification & Dust Collection*
20. *Incinerator for Cleaning Oven Exhaust*

Figure 12.4 Mineral wool plant. Courtesy Roxul Company.

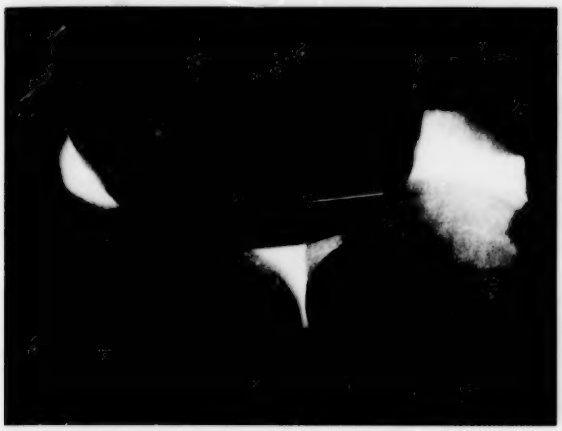


Photo 12.2 Spinners forming mineral wool fibres. Photo courtesy of Roxul Company.

Depending on the end use of the product, different additives may be sprayed onto the fibres at this stage.

In the making of rigid insulating boards and batts, as much as 10 percent of a resin binder is sprayed on the fibre as it is stripped from the spinners by a stream of air. An emulsified oil may also be added at this stage to control dust or for waterproofing.

The air stream not only moves the fibre from the spinning wheels, but effects a partial separation of fibre and "shot", the unfibrized beads of hardened melt. Through a closely controlled air system, the wool is collected uniformly on a conveyor belt whose speed determines the thickness of the mineral wool blanket being formed. A cyclonic separator apparatus has recently been patented which, in combination with a rotating screen filter, separates wool from shot.[25]

Leaving the collection chamber, the wool blanket is directed to any of several product lines. To produce loose wool, the blanket is passed between contrarotating toothed rolls, known as granulators, which shred the blanket and further separate shot that is subsequently removed by screening or cycloning. To produce other products, the blanket can be rolled into pipe insulation, or for rigid boards or batts, the resin impregnated wool blanket is cured in a hot air oven, then cut into any size by circular saws mounted above the conveyor.

New mineral wool products are constantly being developed and patented. A few recent ones include mineral wool with a vertical fibre orientation (resulting in higher strength)[12] autoclave treated mineral wool[26] and desiccant impregnated mineral wool for use as a drying agent.[4]

Loose wool is either bagged or baled, and sold as loose insulation that can be either poured or blown into attics and wall partitions. Densities of boards and batts as high as 250 kg/m^3 (16 pcf) are possible.

Mineral wool products are subject to standards established by the American Society of Testing and Materials (ASTM C 764–73), and the Canadian Government Specifications Board (CGSB 51–GP–9M, 51–GP–10M, 51–GP–11M). These include standards for thermal transmission, specifications for batt insulation and loose fill insulation, loose fill density and mean specific heat.

A final consideration in mineral wool manufacture is an environmental one. A major problem for mineral wool manufacturers is the containment of sulphur–containing flue gases, especially when using metallurgical slags as raw materials. Sulphur is also present in coke. Elaborate collection and incinerating systems may be necessary in these instances to ensure a clean air environment. Natural rock materials are significantly lower in sulphur content, and most of these air pollution control measures are not necessary when they are the raw material.

ONTARIO MINERAL WOOL PRODUCERS

As a result of field and laboratory studies in 1931 by the Mines Branch, Canada Department of Mines, three companies were formed in 1934 to engage in the manufacture of rock wool using argillaceous dolostone from the Niagara area. These companies were:[16]

- The Rock Wool Company of Canada Limited,
- Queenston Rock Wool Limited,
- Spun Rock Wools Limited.

Only Spun Rock Wools Limited achieved sustained commercial production, at Thorold. Its operations are described on the following pages, along with the four slag wool plants which were operating in 1985.

In 1936, Rockwool Corporation (Canada) Limited began production at Brantford using natural rock from the Niagara area,[17] but the venture was apparently shortlived.

Canadian Johns–Manville Company Limited began production of mineral wool at Asbestos, Quebec, in 1935, and was experimenting with some of the local rocks as plant feed.[17] Johns–Manville also produced slag wool at a plant in Scarborough. Gypsum, Lime and Alabastine (Canada) Limited formerly produced wool at Caledonia.

Photo 12.3 Mineral wool fibre before pressing into batts. Photo courtesy Roxul Company.

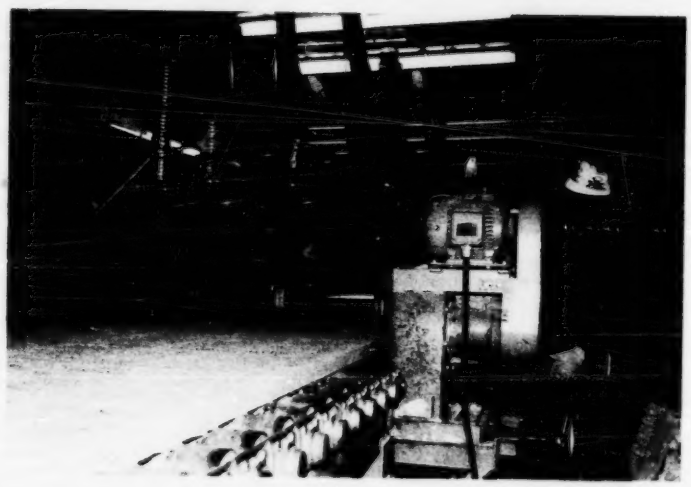


Photo 12.4 Fibre batts after the addition of binder and pressing. Photo courtesy Roxul Company.

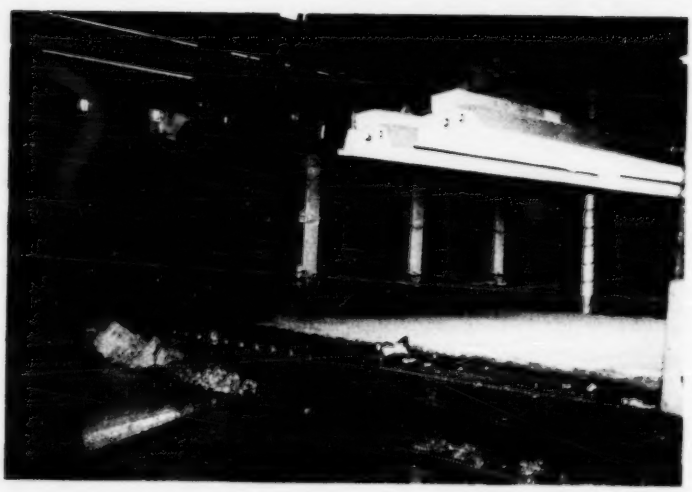


Photo 12.5 Fibre batts cut to width by circular saws. Photo courtesy Roxul Company.

SPUN ROCK WOOLS LIMITED

In 1934, Spun Rock Wools Limited commenced production of rock wool at Thorold using local argillaceous dolostone which had a naturally suitable composition without additives. This stone belongs to the Rochester Formation of the Middle Silurian Clinton Group, a sequence of dolostone and shale 12 to 18 m thick. The formation thins rapidly to the west and north, and suitable stone is practically restricted to a 12 km zone between Thorold and the Niagara River. The Rochester Formation underlies Decew Dolomite, making access difficult except where quarrying has removed the overlying rocks. However, good exposure can be seen at various points in the Niagara Escarpment.

The Rochester Formation consists of dark grey, soft to moderately hard, thin and very thin bedded, fossiliferous dolomitic shale (or argillaceous dolostone) interlayered with hard grey–brown beds of dolomitic limestone that increase in frequency towards the top of the section. Calcite and dolomite actually comprise about 60 percent of the mineral content of the rock.[20]

Suitable stone is accessible in the quarry floors of Queenston Quarries Limited at St. Davids and Walker Brothers Limited at Thorold. In 1932 Queenston Quarries tested the Rochester Formation by drilling, and found it to be 18 m thick at their St. Davids quarry. Laboratory testing by the Mines Branch, Ottawa, indicated the entire section was suitable for rock wool.[18] Chemical analysis of the top 7.5 m is reproduced in Table 12.1. Analysis of a similar section at Thorold is also given in Table 12.1.

Spun Rock Wools Limited developed an innovative process for producing wool at their Thorold plant. Instead of the conventional coke–fired cupola furnace, lump stone was melted in resistance arc type electric furnaces. Fibrizing was accomplished by mechanical means rather than by steam or compressed air.

Three 1 tonne tilting furnaces were used in the plant, two of which were controlled by one operator from a central control station from which the operation of the furnaces and the fibrization process could be observed simultaneously. Furnaces were tapped and charged almost continuously. When the furnaces were tilted, a stream of molten rock was deflected tangentially by a high speed disc, turning at about 4,000 rpm, resulting in the formation of long silky fibres. The operator controlled the tilt, and hence the width of the molten stream, and also the speed of the revolving disc which determined the fibre length.[30]

Wool was removed from the vicinity of the disc by a current of air and directed against the walls of a tub with sufficient force to remove much of the heavier shot, while the wool was collected in a chamber 5 m square. Most of the production was bagged in units of 0.1 m^3. Normal bulk density of the wool was 48 kg/m^3, but for more severe temperature conditions a wool of twice this density was marketed. An unusually white wool could also be made for special purposes. Output was about 2.5 tonnes per day.

Although the process was technically viable, the plant was closed in 1978 for lack of funds for needed plant expansion.

BISHOP FIBRETEK INC.*

Formerly known as Bishop Building Materials, Bishop Fibretek Inc. is located at 21 Fleeceline Road in West Toronto. The company makes mineral wool from a blend of blast furnace slag and sandstone. The slag is received in lump form (–10 cm +4 cm) from National Slag in Hamilton. Sandstone from the Potsdam Formation near Kingston is supplied by D.A. Foley. Both raw materials are stockpiled adjacent to the plant.

A coke–fired shaft furnace, or cupola, is operated continuously, melting the slag and sandstone which are periodically introduced at the top, with coke, in batches of about 450 kg. Coke comprises 16 percent of the batch while sandstone comprises 7 to 16 percent, depending on the end use of the product. The sandstone concentration controls the viscosity of the melt, and the character of the resulting wool fibre is largely determined by viscosity.

The melt collects in a pool at the base of the cupola where air and oxygen are introduced to maintain a peak temperature of 1425–1450°C. Small amounts of molten iron from the slag are periodically tapped from the bottom of the pool. The cupola is essentially a steel shell which is cooled by circulating water. There is no refractory liner except at the base.

Melt is taken by overflow from the pool via an inclined trough, and discharged as a stream onto four spinning grooved wheels. These divide the melt into small droplets which are stretched into fibre by a stream of high pressure air.

Spun material is drawn onto a moving wire belt, forming a blanket that is conveyed through several

*At the time of writing, Bishop Fibretek was in the process of suspending operations.

granulators where non-fibrous shot is separated and subsequently removed. The granulators are spiked cylinders which rotate in opposite directions. Shot is removed on revolving screens which also serve to complete the nodulation of the wool.

There are four main wool products, these being:

1. wool used in the manufacture of ceiling tiles,
2. wool mixed with a cement binder for use as sprayed fireproofing on structural steel,
3. wool mixed with silica fume (very fine silica) for use as an insulation in metal chimneys,
4. wool used in residential insulation.

The first three products are shipped in cardboard-covered bales of 230 to 350 kg, compressed to bulk densities of about 280 kg/m^3. Residential wool is marketed under the name "Fleece Line" in 15 kg bags, either for blowing or pouring as loose-fill insulation. Plant capacity is about 12,000 tonnes annually.

CANADIAN GYPSUM COMPANY

In addition to its gypsum mining, processing and board manufacturing plant at Hagersville, Canadian Gypsum Company produces mineral wool at its plant at 21 Oak Street in Weston. A subsidiary of USG Corp. (formerly U.S. Gypsum), the company commenced operations at the Weston site in 1937. While slag is the basic raw material in the Weston plant, basalt is used in some of the U.S. plants.

The Weston plant was enlarged in 1948. Present capacity is 37,000 tonnes annually but minor process changes are expected to effect an increase to 45,000 tonnes. There are two separate processing lines, each with its own cupola. One produces only granulated wool, while the other produces either granulated wool or wool batts. Fibre is produced using horizontal spinners in a process that favours granulated wool.

Slag from the Hamilton steel operations is supplied to the plant by truck by National Slag Limited. Either nepheline syenite or quartzite is blended with the slag. The addition of nepheline syenite results in a better fibre except for its grey colour; quartzite is used where a whiter colour is preferred.

Coke is the main fuel and is added with the other raw materials at the top of the cupolas; augmentation by natural gas is used in the melting zone.

Granulated wool is the company's principal product, most of which is bagged for shipment by truck. Batts have not been produced since 1980. Approximately 25 percent of CGC's market is in industrial applications such as chimney insulation and other refractory uses; the rest is in wool to be blown for use as loose fill insulation. Renovation and upgrading of the insulation in older homes is currently a significant market. The company also employs its own installers to ensure a constant standard of installed quality.

Canadian Gypsum serves mainly the Canadian market, leaving the U.S. market to its affiliates in that country.

PARTEK INSULATIONS LIMITED

On March 1, 1985, Partek Insulations Limited officially assumed control of Holmes Insulation Limited at 561 Scott Road in Sarnia. The plant was originally opened under the name Holmes Foundry Limited. Partek's parent company, Oy Partek Ab, is a Finnish company with extensive experience in mineral wool production and technology.

The Partek plant is a relatively large producer, employing two cupolas fed by steel slag from the Detroit area. A conventional vertical configuration of four spinners is used. The product is mostly loose wool for industrial uses with pipe wrap as the major application. Most of the production is exported to the U.S.A.

ROXUL COMPANY

Roxul Company is a division of Standard Industries Limited, a major Canadian producer of construction materials. The Roxul plant is located at 551 Harrop Drive in Milton. It is Canada's newest mineral wool producer, in operation since 1980.

The Roxul plant (Figure 12.4) was designed and built with the assistance of the Swedish firm, Jungers, which has been involved in approximately 35 similar installations worldwide. The principal raw materials, coke, slag, silica and nepheline syenite, are received by truck and stored in separate bins. Batches are automatically proportioned and charged to the cupola at the rate of about 8 charges per hour. A typical charge will consist of 450 kg of slag, 60 kg each of sandstone and nepheline syenite, and 90 kg of coke. From the time it is introduced at the top of the cupola it takes about 90 minutes for the raw material to pass through the system.

Slag is obtained from National Slag Limited in Hamilton, nepheline syenite from Indusmin Limited in Nephton, pink sandstone from W.R. Barnes Limited, and coke from suppliers in Tonawanda, N.Y., and Erie, Ohio.

The melting zone at the base of the cupola is maintained at about 1550°C; oxygen injection is

performed at seven points around the base, and air is introduced at fourteen points. The melt is discharged in a thin stream through a vertical configuration of grooved spinner wheels (Photo 12.2). The first wheel is fixed at 3,524 rpm, but the speeds of the other three wheels are variable to a maximum of 7,745 rpm. Simultaneously with the fibrizing of the melt, oil and resin binders are sometimes sprayed onto the fibres as required for subsequent processing.

An air stream conveys the fibres from the spinner wheels to a collection chamber where they settle uniformly onto a conveyor belt. Speed of the belt determines the thickness and density of the wool blanket. The wool blanket can be processed either for loose wool insulation, rolled for pipe insulation or further processed for rigid boards and batts (Photos 12.3–12.5). The loose wool line includes a granulating system and cyclone for the removal of shot, followed by baling or bagging of the loose wool product.

For boards and batts the wool blanket is passed between upper and lower press bands of a curing oven. The adjustable opening between the bands determines the thickness of the finished product. Curing of the resin binder is accomplished by circulating hot air. Board densities as high as 250 kg/m^3 are possible (16 pcf). After discharging through a cooling area, the boards are cut to any desired length, width and thickness.

In 1984 the company produced about 3,000 tonnes of loose wool in bags, 10,000 tonnes in bales and 3,000 tonnes of rigid boards and batts. Most is exported to the U.S.A.

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Part IV — Other Products

Chapter 13 — Art Pottery

INTRODUCTION

Art pottery is a term generally used to describe ware produced by the small manufacturer or hobby potter for decorative purposes. This product range includes vases, ashtrays, figurines and giftware. The definition can also be extended to include decorative but functional pottery such as kitchenware and lamps.

The art pottery industry in Ontario ranges from the "one–man" hobbyist to large lamp manufacturers. The larger operations predominantly use slip casting processes for high output; some companies also employ wet pressing or jiggering and jolleying techniques. The small potters also use slip casting processes and for specialty items, some hand throwing.

The market for art pottery is mainly domestic but a small amount is exported to the U.S.A. The potters face greatest competition from foreign countries such as Korea and Japan where mass production allows less expensive production and consequently cheaper ware.

A large number of ceramic manufacturers use a talc body or #200 casting body for their ware. The raw materials composition of the body is given in Table 13.1. This body was originally developed for the hobby ceramic industry, but has since been extensively adopted by the commercial ceramic manufacturers. Individual manufacturers have adapted the body to their particular requirements by substitution of ball clays or replacement of whiting by barium carbonate or nepheline syenite.

There are several reasons for the industry's use of a talc body. They include:

- cost
- constant availability of raw materials
- wide physical operating characteristics
- wide firing range
- simplicity
- white burning
- very adaptable to most glazes or other decoration types.

The ceramic manufacturers of Ontario can be separated into two groups, (1) those who manufacture their own body and (2) those who purchase a body from a commercial slip manufacturer. The potters, who manufacture their own body may purchase raw materials directly from the source or through a Canadian distributor.

TABLE 13.1 #200 - CASTING BODY.
Cone 06

Talc Nytal 100 HR		64 lbs.
Tennessee #5 Ball Clay		16 lbs.
Kentucky OM #4 Ball Clay		16 lbs.
Whiting		4 lbs.
Total dry weight		100 lbs.
Water		44 lbs.
Soda Ash	1.0 oz	
Sodium Silicate	5.5 oz	

CLAY SUPPLIERS

There are two main commercial slip manufacturers in Ontario, Al–Mac Slip Company of Brampton, and Burl–Mac Slip of Burlington.

Al–Mac Slip company imports clay from the U.S.A., approximately 425 tonnes of ball clay and 710 tonnes of talc are used per year. Of the company's total sales, more than 95 percent comes from the sale of premixed slips. Primary customers include small teaching studios and commercial ceramic manufacturers. Al–Mac also supplies dry mix of a 60 percent talc body.

Burl–Mac imports 500 to 700 tonnes of clay per year from U.S. sources for production of talc body slips. The main buyers of the slip are hobby stores.

The Pottery Supply House in Oakville, Tuckers Pottery Supply in Markham and Stratford Clay Supply of Stratford also supply clay bodies to the ceramic manufacturers.

Pottery Supply House supplies a talc body and various other specialty bodies for their customers. The company imports 200 tonnes of clay per year from the U.S.A. They also use over 130 tonnes of clay per year from a fireclay mine in Nova Scotia that they operate. In addition to being a raw material source, the company supplies glazes, kilns and equipment to the hobby industry.

Tuckers Pottery Supply produces pugged clay for potters and also supplies small amounts of dry material. The company sells in total approximately 30 bodies ranging from earthenware through to porcelain. Custom blended mixes are also available. Most of the bodies are sold to professional potters with some sales to the hobbyist and schools. Clay is imported mainly from American sources, roughly 1

TABLE 13.2 SELECTED ART POTTERY MANUFACTURERS IN ONTARIO.

Company	Plant Size	Raw Materials: Types and Sources	Annual Clay Consumption	Process	Products and Market
Antony's Art Design Toronto	Medium ~30 employees	- use talc body - buy raw materials from Ferro, prepare own slip	~130 tonnes	- slip casting - fire in 17 hobby kilns.	- manufacture ceramic lamps and accessories - sell to retailers, distributors in Canada U.S., and Australia - export ~10%.
Alan R. Daly Ltd, Toronto	Medium ~25 employees	- clay from United States bought through Al-Mac - slip prepared in-house	~135 tonnes	- slip casting - fire in 4 electric intermittent kilns	- manufacture lamps, vases ashtrays - serve domestic and foreign markets, sales to U.S. just opened.
Aristocrat Lamp, Toronto	Medium ~20 employees	- obtain clay directly from American sources	~135 tonnes	- slip casting	- ceramic lamp and vase manufacturer - sell product across Canada.
Edgewood Potteries Toronto	Medium ~20 employees	- import clay directly from United States - slip mixed in-house	55-90 tonnes	- slip casting process - fire in 5 electric intermittent kilns	- manufacture vases, deli-bowls and giftware. - market product across North America, ~25% exported to U.S.
Horizon Ceramics Erin	Small ~8 employees	- talc body - obtain clay from Pottery Supply House	25-45 tonnes	- use 4 large electric shuttle kilns	- no longer sell mixed clay to hobbyists, now sell only finished ceramic ware, i.e. lamps vases and accessories.
MBM Ceramics Ceramics Erin	Medium ~20 employees	- kaolin body - mix own slip using clay imported from United States	410-450 tonnes	- slip casting process - 3 electric kilns - modern plant using state-of-the-art equipment	- mainly produce bath-room accessories.
Royal Ceramics Weston	Medium	- talc body - get clay directly from U.S. sources	~180 tonnes	- slip casting - electric intermittent kilns, 2 large 1 small	- manufacture lamps, vases and accessories - sell to retailers only
Smith & Stone Ltd Georgetown	Large	- obtain clays from the United States	~330 tonnes of ball clay ~155 tonnes of kaolin		- electrical porcelain (major) bathroom accessories (minor) - market includes Canada, United States, and previously, some work in South America.
Sunrise Fine Bone China Co. North York	Medium ~30 employees 20 of whom are handi-capped	- kaolin body - import clay from the United Kingdom.	~90 tonnes	- at present slip casting process only but are chang-ing process to include jiggering and jolleying	_ produce fine bone china teaware, giftware and hotelware - export ~15% to United States and New Zealand

TABLE 13.2 CONTINUED.

Company	Plant Size	Raw Materials: Types and Sources	Annual Clay Consumption	Process	Products and Market
McMaster Pottery Dundas	Medium 15-20 employees	- produce a red body using residual clays - 63% local ball clay obtained from Ferro	~3.5 tonnes ball clay	- use slip casting and pressing techniques - fire in small gas fired tunnel kiln	-manufacture artware and tableware - supply chain stores predominantly, export ~2% to the U.S.
Pic-N-Do Oakville	Small	- mainly talc body - clay mix is purchased from Ferro	~70 tonnes	- slip casting - fire in 7 hobby kilns	- produce finished ceramic ware. - market product wholesale to distributors and retailers.
G.B. Distributors	Small 8 employees	- talc body - purchase slip from Burlington Ceramic (Burl Mac)	~700 litres slip per week	- slip casting - use 7 large hobby kilns	- produce kitchen and houseware. - selling to Canadian retailers.
Blue Mountain Collingwood					
Rainbow Pottery Collingwood	Medium 12 employees	- use local clays and Queenston shale (from Shelburne area)	~225 tonnes	- slip casting - produce porous body suitable for dip glazing	- produce giftware, vases and accessories - exports count for ~20% of total sales.
Northwind Stoneware	Small 3 employees	- use clay from United States bought through Stratford Clay Supply	~7 tonnes	- slip casting, hand throwing no longer used - fire in 6 small hobby kilns	- produce kitchenware, oven ware and functional pieces
Janes Pottery Factory North Bay	Small 4 employees	- stoneware body - buys raw material from Tucker Supply and mixes slip in-house	~2 tonnes	- 85% slip casting, 15% hand throwing - fires in electric shuttle kiln	- produces functional pottery, popular piece being a creamer milk jug
Don Zver Pottery Troy, Ontario	Small-medium Employs 5-7 full or part time staff	- buys stoneware body, wet mix from Pottery Supply House	14-15 tonnes	- hand building or throwing process	- sells ware to Southern Ontario market, majority of sales from studio

million kg per year. Some clay is also brought in from the United Kingdom.

Ferro Industrial Products in Oakville and Chicago Vitreous in Ingersoll may also be included as sources for raw materials for potters. While their primary function is the manufacture of glaze or enamel frits, they also supply clay to small potters and the appliance industry, the latter for use in glaze or enamel batches. For small potters, Ferro will recommend a body formula and provide the component raw materials. No data were available from these two companies on quantities of clay sold to ceramic manufacturers and potters.

ART POTTERY MANUFACTURE

Ontario has numerous art pottery manufacturers; the majority are small producers employing fewer than 10 people. While the numbers are too great to do an exhaustive study, several manufacturers were

surveyed to obtain an overall view of the industry with particular regard to clay sources and consumption. A summary of the findings is presented in Table 13.2. Some of the larger manufacturers have been reviewed in greater detail.

As a general summary of the art pottery industry in Ontario it can be said that:

- most clay is imported from U.S. sources;
- the larger companies produce mainly lamps and vases using a talc body;
- the market for Ontario art pottery is mainly domestic with a very small amount exported to the U.S.A.

MBM CERAMICS

MBM Ceramics is a manufacturer specializing in bathroom accessories in colours designed to match the colours of the major sanitaryware producers. The product line presently includes in–wall soap trays, vanity soap dishes, towel racks, etc.

History

MBM Ceramics was initially started in the mid–1970s in Downsview, Ontario, operating in a plant of about 800 m², producing bathroom accessories. In November of 1983 MBM was purchased by Olympia Tile of Toronto. Olympia had a brand new plant of 2800 m² commissioned at the company's present location which opened in March 1985. The product line has since expanded from two series of styles produced at the old plant to six series of styles complementing all three major sanitaryware producers. Products are available from a selection of 49 colours. The marketing of MBM's products is handled by Olympia Tile.

Plant

MBM can be considered a "state–of–the–art" plant with respect to the type of processing that is employed (see Photos 13.1 to 13.5). All ceramic greenware is produced by slip casting, and the finished glazed product produced by fast–fire, single–fire. The plant is broken down into the various processing areas of casting, unmoulding, drying, fettling, glazing and firing with each stage connected by a conveyor line. The conveyor line is computer linked to each area with the speed control geared to the automated fettling and glazing stations. The plant is geared towards automating any aspect of the process that can be.

Processing

The processing starts off with the mixing of bagged raw materials into the casting slips. Two 900 litre blungers are used for batch mixing. Slip from each blunger is pumped to a 4500 litre holding tank where it is slowly mixed to remove trapped air and stabilize. The casting slip formulation is similar to body formulations used by the sanitaryware industry.

Slip is pumped to three casting stations. The moulds are cast for 1–1/2 hours, drained and allowed to dry for 1–1/2 hours before unmoulding. The greenware is hand–loaded onto trays and microwave dried in a system developed with the assistance of Ontario Hydro. The dried ware is conveyed to the automatic fettling stations where rotating abrasive pads remove excess flash from the mould seams. The fettled ware then travels to the glazing booths. At present, one robot spraying station is operating, while three manual spraying stations are set up for more flexibility of colours. The glazed greenware is hand–loaded onto kiln cars and fired in fibre lined electric kilns.

The ware is fired up to ~1200°C with a 6–hour rise and 6–hour cool firing schedule. The thermal profile and firing schedule for each kiln is fully monitored and controlled by computers. The plant has three fibre lined computerized electric kilns; two are about 4 m deep and one about 6 m deep.

Production and Raw Material Consumption

Annual production is estimated to reach 410 tonnes per year or over 600,000 pieces. Raw material consumption includes:

- ball clay from Kentucky and Tennessee,
- nepheline syenite from Ontario,
- kaolin from U.S.A.,
- flint from U.S.A.

Market

The company markets 90 percent of its product in Canada. The remaining 10 percent is exported.

Future Plans

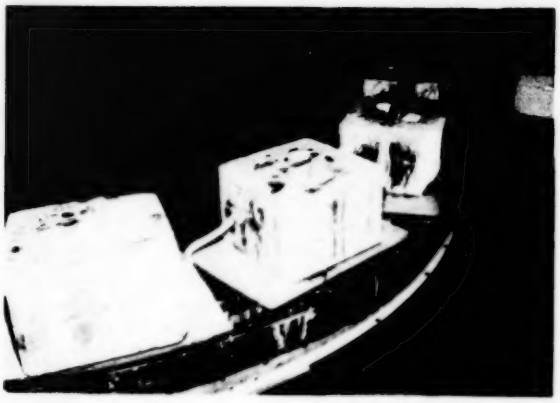
A new tile decorating line is currently under preparation to produce matching tile and bathroom accessories.

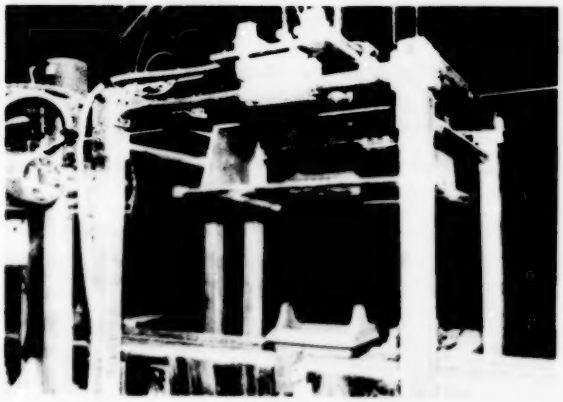
The company intends to speed up production by installing more microwave facilities. Microwave drying will be applied to:

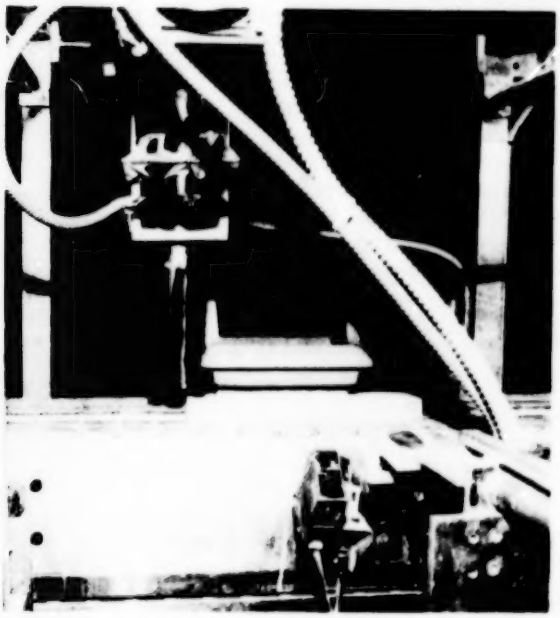
- mould drying,
- accelerating casting time,
- greenware drying.

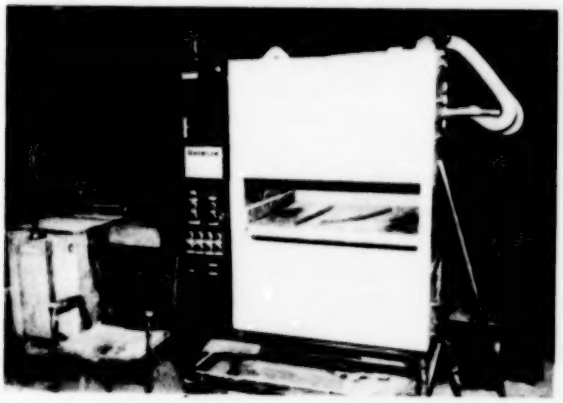
SUNRISE FINE BONE CHINA CO.

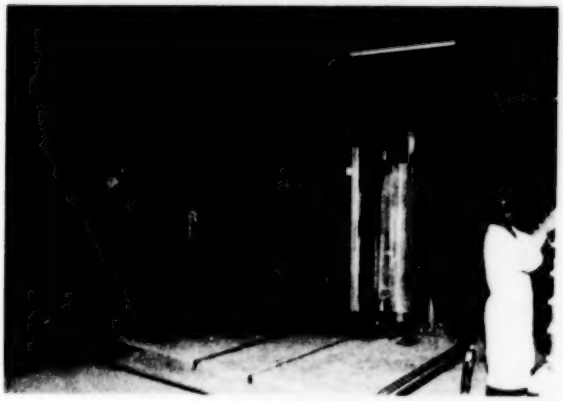
The history of the development of bone china dates back to 1749 when the Bow pottery factory in England took out a patent for a body produced from "animals, vegetables or fossils". Chemical analysis of this ware indicated a calcined bone content of 40











Photos 13.1 to 13.5. Top left: conveyor feed casting line; bottom left & top right: automatic fettling machine and conveyor; centre right: microwave drying oven; bottom right: ceramic-fibre lined electic kilns. Photos courtesy of MBM Ceramics.

percent. It is presumed that the bone was used to give rigidity to the porcelain body on firing and to reduce previously high firing losses.

Josiah Spode II was the first potter to achieve success in producing a "profitable" bone china body. His range of recipes cover all of the current compositions used in Britain's bone china industry.

Bone china is prized for its whiteness, reflectivity and translucency.

The traditional recipe for bone china is:

- 50 percent bone ash,
- 25 percent china clay,
- 25 percent cornish stone.

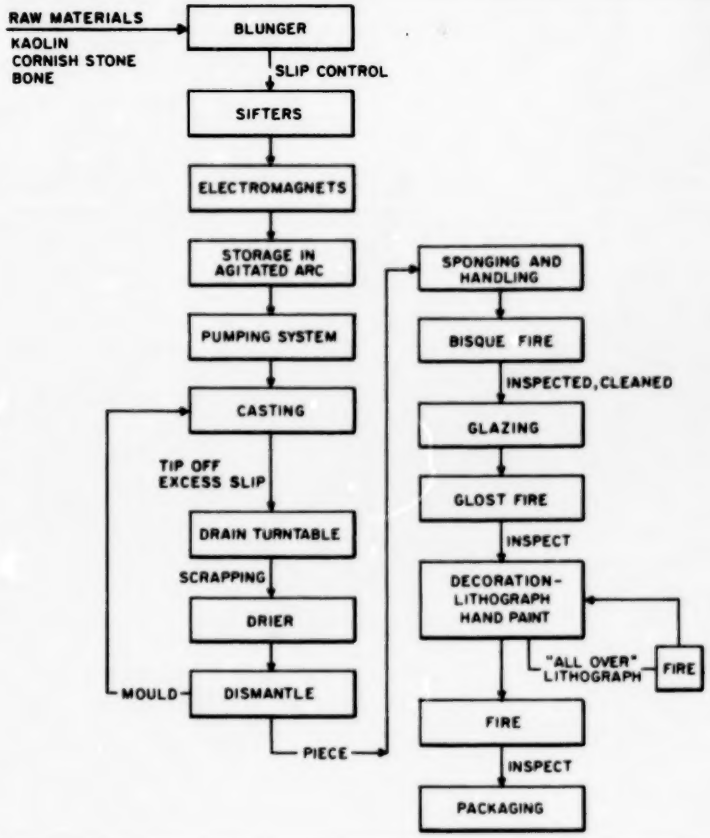


Figure 13.1 Process flow chart for fine bone china.

Attempts have been made to replace bone ash in the recipe by mineral alternatives. These have been, for the most part, unsuccessful, primarily because of colour problems, i.e., loss of whiteness and translucency.

Sunrise Fine Bone China Co., located in North York, Ontario, is the only company in Canada manufacturing bone china. The company was founded by Dennis Salt in May, 1983.

With the assistance of the Metro Toronto Association for the Mentally Retarded, the company employs and trains about 20 mentally handicapped persons. These employees have proven to be dedicated and capable, producing quality ware for competition in the world market.

Sunrise exports approximately 15 percent of its product to markets in the U.S.A. and New Zealand. The company manufactures tea ware, gift ware and hotel ware. The artwork for the ware is professionally designed for them and often reflects a "Canadiana" theme, such as flowers, wildlife or Canadian culture.

At present, Sunrise employs a slip casting process (Figure 13.1), but is developing facilities for jiggering and jolleying. Raw materials are imported from the United Kingdom. Approximately 100 tonnes of kaolin are used in one year.

BLUE MOUNTAIN POTTERY LTD.

History

Blue Mountain Pottery was started in 1949 by Joso Weidner and flourished as a family business until 1967, when it was purchased by International Silver Company of Canada Limited, a wholly owned Canadian subsidiary of International Silver Company of the U.S.A. Under this management the company grew rapidly and became internationally known.

Heritage Craftsman Ltd. of Toronto, a wholly owned Canadian company, purchased Blue Mountain in 1972. Within a few years the new owners increased sales by about 80 percent. In 1982 the company again changed hands as Triarch purchased over 60 percent of the shares while operating as a holding company. In 1985 Benson Lilly took over the operations. After 1984 sales tailed off and ex-

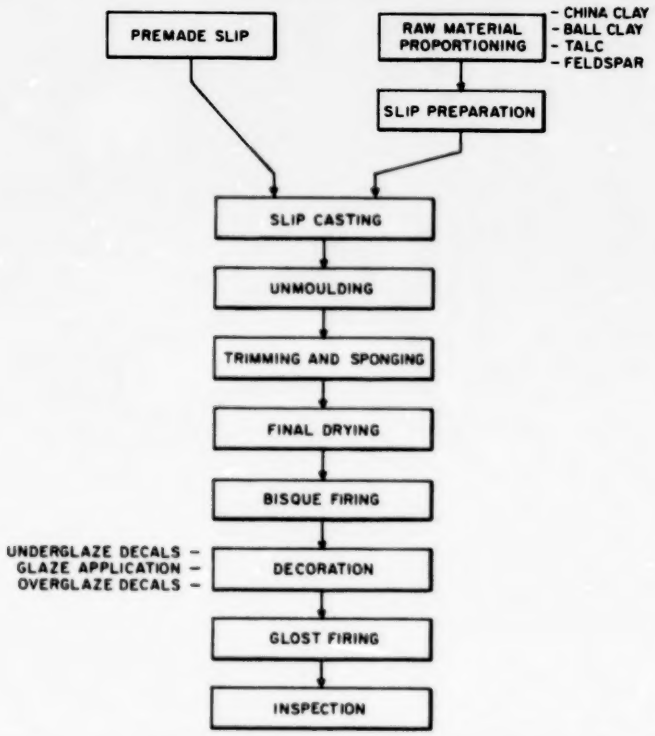


Figure 13.2 Process flow chart for giftware production by slip casting method.

penses rose until bankruptcy was declared in late 1985.

Blue Mountain traditionally operated as both a tourist attraction and manufacturing operation. A factory retail outlet has always attracted a large number of visitors. Betwen 600,000 and 700,000 people visited the plant and outlet annually, labelling Blue Mountain as the largest tourist attraction in Huronia.

At its peak, Blue Mountain employed up to 175 people, often operating with two shifts. The plant is situated on 5500 m^2 of manufacturing and administrative floor space.

Products

Blue Mountain Pottery is known worldwide for its traditional glazed ware of blue–green on a gloss black. Giftware figures in this glaze were the mainstay of the company for years until a new line of cookware was introduced in the early 1980s. The cookware, Country Charm, was marketed as a complete line of in–oven cookware plus a host of matching kitchen accessories. Country Charm accounted for up to 50 percent of production and sales in the later years of operation.

A wide range of other giftware and souvenir items of assorted colours accounted for about 10 percent of sales.

Processing

Raw materials consist of Ontario shales, wollastonite and minor additions of nepheline syenite. The shales are purchased by the truckload and stored outside in large mounds for weathering. Three shales are used which include:

- Queenston shale from Cheltenham or Georgetown,
- Meaford green shale,
- Meaford blue shale.

The raw materials for body processing are all wet mixed. Two 4500 litre high–speed blungers are charged with the shales, wollastonite and nepheline syenite. Two types of bodies are prepared: a slip casting body (Figure 13.2), and a ram pressing body (Figure 13.3). The blend of the shales varies for the type of body but generally they account for about 85 percent dry weight for either body formulation.

The materials are mixed with sufficient water to produce a fluid mix. After the shales are broken down (about 4 to 6 hours per mix), the slurry is pumped through 60 mesh screens to large holding tanks. In one tank the casting slip is made up with a

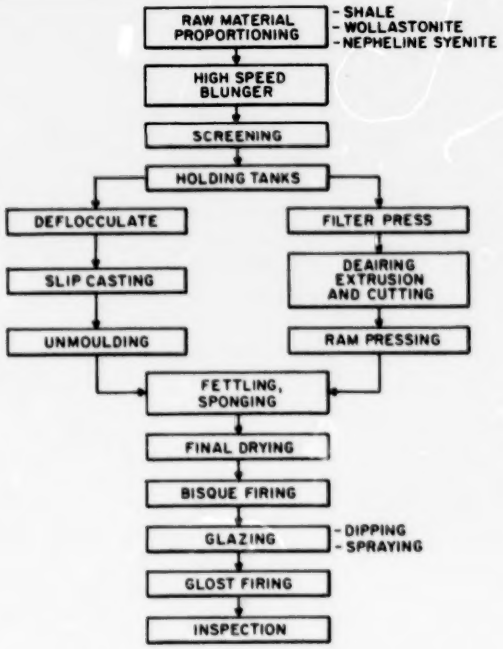


Figure 13.3 Process flow chart for earthenware pottery production by ram pressing method.

specific gravity of ~1.83, while the pressing body is prepared for filter pressing with a specific gravity of ~1.76.

The casting slip is pumped to the casting station where an operator fills stationary racks of moulds. Excess slip is drained off and the castings allowed to dry prior to unmoulding. After unmoulding (Photo 13.6), the greenware is hand loaded onto rack trolleys and dried in air overnight. The dried ware is fettled and sponged by hand and ready for glazing.

The pressing body is filter pressed and the filter cakes pugged and extruded under vacuum into billets of a set size. Two extruders run continuously during peak production. The billets are transported to the ram pressing area where three presses function to produce flatware and trays and deep–sided bowls and casserole dishes.

All greenware is bisque fired to around 830°C, with a 12–hour cold to cold schedule. The bisqueware is then glazed, much of which is done by hand dipping, but recently spray glazing stations were set up (Photo 13.7). The glazed ware is glost fired to 1050°C with a 12 to 13 hour schedule. For the Country Charm line, a third firing is required to fix a decorative decal onto the glaze surface. All fired ware is hand inspected and then passed on to packaging.

Photo 13.6 Dismantling plaster of paris mould used in slip casting ware. Photo courtesy of Blue Mountain Pottery.

Photo 13.7 Manual spraying of glaze onto ware. Photo courtesy of Blue Mountain Pottery.

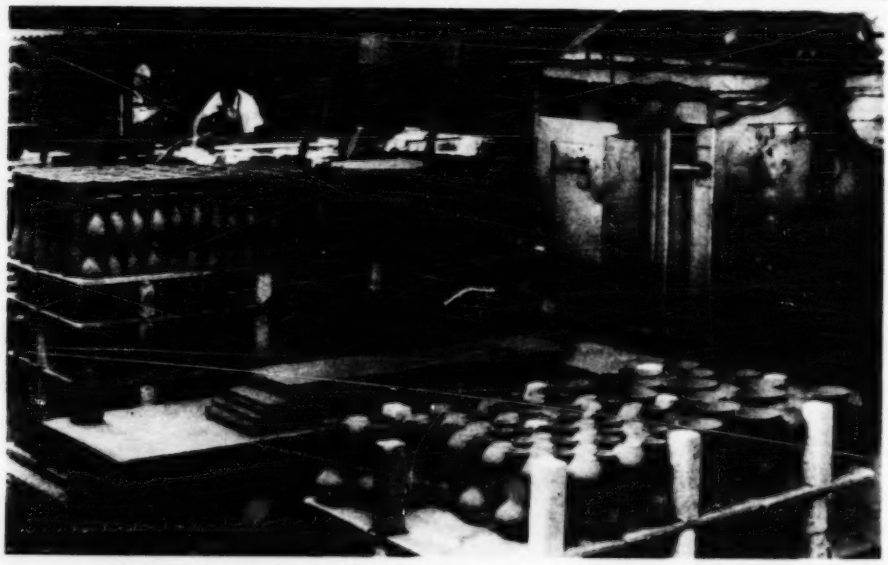


Photo 13.8 Ware stacked on kiln cars for firing in electric intermittent kiln. Photo courtesy of Blue Mountain Pottery.

The plant has several 2.5 m deep electric wall kilns which are not continuously used but are available during peak production. The majority of the firing is carried out in five Unique 2.7 m deep electric shuttle kilns built on tracks (Photo 13.8).

Production*

Total sales in 1983 reached about $4 million and dropped to $3 million in 1984. The sales were almost split evenly between the Country Charm and the traditional green/black giftware. Annual production of pieces for 1983 was:

- 370,000 pieces cast,
- 560,000 pieces pressed.

Raw material consumption approached:

- 1,000 tonnes/year shale,
- 100 tonnes/year wollastonite,
- 50 tonnes/year nepheline syenite,
- 30 tonnes/year EPK kaolin for glazes, for both the casting and pressing bodies combined.

Monthly production involved approximately:

- 30 mixes ~2000 kg dry weight for pressing,
- 10 mixes ~3000 kg dry weight for casting.

DON ZVER POTTERY

History

Don Zver began his career as a potter in high school. Since that time, he has worked professionally in three pottery businesses. In 1972 he worked for one year in a co–operative with another potter and weaver. From this, he moved to his father's farm in Troy, Ontario, where he opened his own pottery business. In this location for nine years, he produced ware similar to his present product line, working with the assistance of two hired apprentices. In 1980 Mr. Zver purchased his present location and opened to the public in 1983. He currently employs three full time staff which will be increased to five in the summer months. Several part time workers are also employed.

Production and Process

Don Zver Pottery is a manufacturer of handmade functional pottery. The stoneware body is purchased as a wet mix from Pottery Supply House. Approximately 14–16 tonnes of clay mix is used in one year.

The handmade ware is produced by wheel throwing and hand building. A very minor part is extruded.

After forming, the ware is dried and then bisque fired. The company has two kilns, one large 5.7 m^3. gas fired car kiln and another small (0.2 m^3) electric kiln. After bisquing, the ware is glazed, all glazes used being mixes formulated by Mr. Zver. The ware is then fired to cone 10 in a reducing atmosphere.

Don Zver Pottery sells about 60 percent of its ware from the studio at the plant. The rest is sold from shops serving the southern Ontario market.

*At the time of writing, Blue Mountain Pottery was closed due to bankruptcy.

Chapter 14 — Clay Roofing Tile

INTRODUCTION

The two main requirements for roofing tiles (Photo 14.1) are that they be weather resistant and aesthetically attractive. In general, clays and shales offer pleasing and durable fired colours not easily matched by other materials. However, the common clays and shales of Ontario do not fire to a sufficiently dense and impervious condition to resist deterioration through freezing and thawing. Hence, the growing market for masonry roofs in Ontario is the result of recent local production of concrete roofing tiles.

RAW MATERIAL

Clay roofing tiles can be made from those ball clays, fireclays or stoneware clays that have good plasticity and low absorption after firing. Some specifications allow water absorption as high as 3 percent, others as high as 10.5 percent. But the issue is really whether the tile can tolerate repeated cycles of freezing and thawing without breakdown. For the same reason, limestone fragments are deleterious unless finely ground to prevent pop–outs on slaking. Pyrite inclusions and soluble salts are undesirable because of rusty discolourations and efflorescence, respectively. A fine, close–grained, dense–textured, highly plastic clay is preferred, to which sand can be added to achieve optimum density and workability.

Photo 14.1 Imported clay roofing tiles, London, Ontario. Photo courtesy of B.H. Feenstra.

TECHNOLOGY

GERMANY

A typical German plant takes air–dried clay and grinds it to about 20 mesh. It is allowed to age in covered storage for 1 to 3 months, while further clay is added in layers. Ultimately, it is reclaimed by scooping through the layers to ensure uniform plant feed.

Interlocking tiles formed by pressing are generally preferred, but plain or concave tiles produced by an extrusion process are also common. The pressing method produces tiles individually or in multiples at the rate of 15 to 30 per minute. Optimum pressing rate must be determined in each case since it has a significant bearing on the quality, density and absorption characteristics of the fired product.

In the pressing method, mould design also plays a significant role in the quality of the fired tile.[3] Moulds may be entirely of steel, but more generally have a plaster or rubber inlay. Plaster moulds are best for soft plastic clays, but the plaster liner is relatively soft and must be replaced rather frequently. Moulds with rubber membrane or inlay are widely used and more durable.

Drying is normally carried out in continuous tunnel dryers or periodic chamber dryers. The objective is to reduce moisture levels in the greenware to about 2 percent. Drying time is typically 20 to 40 hours under conditions of close humidity control.

Firing is accomplished in tunnel kilns unless production levels are less than 6 to 8 million tiles per year, when Hoffman–type chamber kilns are more economical. A U–shaped frame structure allows the stacking of tiles on kiln cars without the tiles contacting one another. It also permits automatic loading and unloading, and results in an overall reject rate of less than 2 percent.[3]

Packaging is usually by shrink–film wrapping of a stack of tiles on a pallet base.

FRANCE

Recent French technology includes an unusual kiln design.[4] An air–dried plastic clay is ground to 18 mesh, tempered with water (water of plasticity should be 20–21 percent), and extruded into slabs 2

cm thick. Extruded slabs are stamped into desired tile shapes, dried, and fired in fibre–lined pool kilns. These kilns are unique in that the cars are sealed by water in the bottom of the kilns, and only the tiles are exposed to heat. A fast firing schedule of 12 hours is possible, and circulating water temperature is not permitted to exceed 90°C.

Overall plant design is highly automated, one operator controlling the entire manufacturing cycle. The computerized process adjusts all subsequent steps to the speed of the tile press. Fired tiles have absorptions of 3 to 5 percent.

UNITED KINGDOM

According to historical records, clay roofing tiles have been produced in England since AD 54.[5] While 100 years ago there were 50 producers, in 1983 there were only seven represented by the Clay Roofing Tile Council. Low point in production was 1970 when only 953,000 m² of tiles were produced, compared with 3,500,000 m² in 1960. Current production is about 1,600,000 m², about 5 percent of the total roofing tile market of 30,000,000 m² per year. Concrete tiles account for most of the rest (Table 14.1).

TABLE 14.1 MARKET SHARE OF VARIOUS ROOFING MATERIALS, UNITED KINGDOM, 1980.(5)

Roofing Material	Percent
Concrete tiles	90.0
Clay tiles	4.5
Asbestos-cement slates	4.0
Natural slates	1.0
Bitumen shingles	0.3
Cedar shingles	0.2

TABLE 14.2 BRITISH STANDARD SPECIFICATIONS FOR CLAY PLAIN ROOFING TILES.

Minimum Transverse Strength		778 N
Maximum Water Absorption		10.5%
	Length (mm)	Width (mm)
Maximum Manufacturing Size	268	168
Minimum Manufacturing Size	262	162
Work Size	265	165
Thickness		10 – 15 mm
Camber – cross		no limit
– longitudinal	1/2 thickness – 1/2 thickness + 3 mm	

Source: British Standard Specification 402, 1979

The standard roofing tile in the United Kingdom measures 27 cm by 16.5 cm (10–1/2 x 6–1/2 inches), unchanged for 500 years. Tiles are formed from close–grained, dense–textured, plastic clay, either by extrusion or by hand. British Specification 402 (1979) defines the limits for water absorption, apparent porosity and transverse strength, as well as dimensional and shape tolerances (Table 14.2).

CONCRETE ROOFING TILES

The only producer of concrete roofing tiles in Ontario is Marley Roof Tiles Limited. Although only recently established in Canada, Marley has become one of the world's largest manufacturers of roofing tiles, with 28 plants in seven countries. The company was established in 1924.

Marley produces an interlocking roofing tile 413 by 330 mm in overall size at its Milton plant. Made from a mixture of portland cement, graded fine aggregate and colouring oxides, the tiles are extruded in six shades of grey, brown and red. The tiles are designed to be interlocking and overlapping to prevent the capillary action of creeping moisture, and their density is sufficient to resist damage by freezing and thawing.

Installation of a Marley roof takes about three times as long as a conventional shingle roof. The company maintains its own installation crews and stocks of the necessary thermoply underlay, wooden battens and other tile accessories.

SOME ECONOMIC ASPECTS

Improved drying and firing efficiency is a major element in the competition with concrete roofing tiles, which substantially undersell the clay tile market in the United Kingdom (Table 14.3). An innovative drying technique developed in Italy and further refined in Switzerland, involves cyclic bursts of hot air by mobile or rotary blowers.[3] Improved efficiency results from an interrupted air flow which better allows moisture within the tiles to migrate to the surface.

TABLE 14.3 COMPARATIVE COSTS OF ROOFING TILES IN THE UNITED KINGDOM, 1980.

Tile Type	Percent of Total Dwelling Cost
Concrete interlocking tile	2.3
Asbestos-cement corrugated sheet	2.7
Asbestos-cement slate	3.1
Concrete plain tile	3.4
Clay plain tile (machine made)	3.6
Natural slate	3.8
Clay plain tile (hand made)	4.6
Concrete tiles (stone finish)	7.7

Conventional kiln efficiency is very low, whether using continuous tunnel kilns or various pe-

riodic kilns. Theoretical energy requirements are only about 250 kJ per kg of ware, but actual energy expenditure is 2000 to 3000 kJ per kg.[3] Kiln cars and stacking furniture, which unavoidably absorb much energy, are a major barrier to greater kiln efficiency. Hence, submersion of the kiln cars in a circulating water bath while the tiles on top are being fired, as in the French plant previously described, minimizes heat loss. So too the Hepworth roller kiln, described in Chapter 6, which has made clay sewer pipe competitive with concrete and plastic pipes in the United Kingdom. Both kiln designs are highly efficient and operate on short firing cycles, 12 hours and 1 hour, respectively.

The highly automated French roofing tile plant previously described is said to cost U.S. $4.5 million for a productive capacity of 6 million tiles per year.[4] Selling price for the tiles is U.S. $26 per 100.

The main advantage of concrete roofing tiles in the United Kingdom is comparative cheapness; they undersell clay tiles by one–third.[5] The cost of using various types of tile on the roof of a typical two–storey three–bedroom house in the United Kingdom is shown in Table 14.3. Re–roofing of other homes accounts for three–quarters of the United Kingdom market for clay tiles.

In Ontario, concrete tiles are a luxury roofing material. Clay tiles are not generally available. According to Marley Roof Tiles Limited, the makers of the only masonry roof tiles in Ontario, installation of a concrete tile roof takes 2–1/2 to 3 times as long as for a conventional shingle roof using Marley's own roofing crews. And the overall cost is comparable to that of a cedar shake roof — at least four times the price of an asphalt shingle roof. But whereas asphalt shingles have a useful life of 10 to 15 years, Marley roofs carry a 50–year warranty.

Lack of suitable clay is the principal reason for there being no domestic clay roofing tile industry. Canada's climate demands a clay body free from failure by freezing and thawing; hence low limits on water absorption. Ontario's common surface clays and shales do not vitrify to sufficient density unless they are overfired, at which time warpage typically takes place. In a recent study of the clays and shales of south–central Ontario, Kwong et al.[2] found only five samples that could be fired to absorption levels between 6 and 10 percent without noticeable warpage. While British specifications allow absorptions up to 10.5 percent, Ontario experience indicates the danger of failure by freezing at this level.

Nevertheless, there continues to be serious interest in the possibility of manufacturing roofing tiles from Ontario shales in at least three operating plants. However, Meaford Tile Limited had its Georgian Bay Shale evaluated by roofing tile specialists in Germany in 1982 with unfavourable results.

Local clay was used by Hill Tile Limited of Stevenson, Kent County, in a short–lived attempt at commercial production of clay roofing tiles a few years ago. The plant had been a major producer of clay drainage tiles for many years.[1] Dresden Tile Limited also seriously considered clay roofing tile before closing in 1985, but found its fired clay to be too porous.

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Chapter 15 — Clay Flowerpots and Filter Tile

INTRODUCTION

Halton Ceramics Limited in Burlington is the only producer of clay flowerpots and filter tiles in Canada. Although plastic flowerpots dominate the market, imports of clay pots from the U.S.A., Germany and Italy are substantial. Plastic pots are cheaper, lighter, non–abrasive, more easily stored and handled, and less easily broken. But porosity in clay pots encourages better root development, and at the retail level plants sell better in clay than in plastic pots for aesthetic reasons.

The annual Canadian market for clay flowerpots is estimated at about 7 million, three–quarters of which are of standard shape and in diameters from 5 to 25 cm. However, a strong market exists for larger standard and specialty shapes to 50 cm diameter where they are preferred on the basis of appearance. Sales are about equally divided between greenhouse growers and retail distributors. Growers buy in volume and tend to prefer the cheaper plastic pots, while retail sales are based more on appearance and favour clay. The annual Canadian market for plastic flowerpots is about four times that for clay pots.

RECENT ONTARIO PRODUCERS

The principal producer of clay flowerpots for many years was the Foster Pottery Company in Hamilton. The plant was destroyed by fire in the 1970s and did not re–open. More recently, flowerpots were produced with drainage tiles by Dochart Brick and Tile Company Limited at Arnprior; the plant closed in 1984. Other producers in Quebec (Montreal Terra Cotta Limited) and British Columbia (Haney Pottery Limited) were closed in the mid–1970s. Dresden Tile Yard Limited, at Dresden, Ontario, also considered clay flowerpots before ceasing its drainage tile production in 1985. Halton Ceramics Limited of Burlington was the sole Canadian producer of clay flowerpots in 1985.

DOCHART BRICK AND TILE COMPANY LIMITED

Clay flowerpots were a relatively recent product of this company. Primarily a producer of clay drainage tiles, production of tiles ceased in 1982 and flowerpots in 1984. The original plant was built on this site in 1868. It was located on the north side of Arnprior in lots 7 and 8, concession XIII, Township of McNab, Renfrew County. Descriptions of earlier operations are given by Baker,[1] Keele,[4] Montgomery[5] and Guillet.[3]

Stratified Champlain marine clay and silt exposed in an adjoining pit was worked to depths of 3–6 m. Once a year sufficient clay was excavated, blended with sand and silt, and worked over to ensure uniformity. Drainage tiles were produced during the summer months; flowerpots during the winter. Annual flowerpot production was always second in importance to tile sales, except in the last several years when the company attempted to survive primarily on pots. Common sizes were 5 to 25 cm in diameter, and most sales were direct from the company to greenhouses, hardware stores and other retail outlets in the Ottawa area.

FOSTER POTTERY COMPANY LIMITED

Foster Pottery was the principal source of clay flowerpots in Ontario for many years. Located on Frid Street in Hamilton, the first plant was built on this site in 1876, primarily to produce teapots and urns. Ownership of the plant stayed with the Foster family from the beginning, until it was destroyed by fire in the 1970s. An earlier description is given by Montgomery.[5]

For most of its productive life, the plant produced clay flowerpots exclusively. Using first the high–quality red surface clays derived from eroding Queenston Shale, the company subsequently obtained weathered shale from various locations.

The plant was operated on three levels, with the raw clay being received in a pug mill on the lowest level. Nothing but water was added to the clay, and that only to provide sufficient plasticity for extrusion. The extruded clay stream was cut into plugs for storage and later processing. Plugs were reclaimed from storage as necessary and put through a second pug mill and extruded to produce plugs of the correct size for the size of pots being made. Elevated to the top floor of the plant, these plugs were shaped on presses and placed on long wooden boards for drying.

Drying racks were located above the four beehive periodic kilns, using excess kiln heat. Firing time in the beehive kilns averaged 30 hours. A single shuttle kiln was installed in 1961[2] to augment the firing capacity. It not only cost less to operate than the beehives, but improved production time by permitting a 24–hour turnover.

Following a fire in the 1970s, the plant did not re–open. The flowerpot presses were subsequently acquired by Halton Ceramics Limited.

HALTON CERAMICS LIMITED

Halton Ceramics Limited, located at 1200 Unsworth Avenue in Burlington, was previously operated under the name of Natco Clay Products Limited, and prior to 1954 as the National Fireproofing Company of Canada. The plant was built in 1910 to take advantage of the excellent red "Aldershot" clay that was used by numerous plants in the Burlington and Hamilton areas for bricks, structural tiles, sewer pipes, flowerpots and other pottery products. Descriptions of earlier operations at the plant are given by Keele,[4] Montgomery[5] and Guillet.[3]

The company produces clay flowerpots and a wide variety of hollow tiles for structural, partition and filtration purposes. About 10,000 tonnes of finished ware are manufactured annually by a work force of fifteen. In 1985, clay flowerpots and filter tiles were the principal products, and this plant was the only one in Canada producing them.

Queenston Shale is now used exclusively, obtained from both the company's own adjacent quarry and the National Sewer Pipe quarries on nearby King Road. A year's supply is stockpiled at the plant during the summer months and reclaimed as needed by front–end loader.

The plant process has changed very little over the years. Primary crushing of the shale is still accomplished in a Stevenson single–roll toothed crusher. A 3 m Chambers pneumatic drypan is in closed circuit with two 16 mesh screens. Additional grinding capacity from a Berg drypan is available if needed. Ground shale is stored in two steel bins of 25 and 50 tonne capacities.

Shale from storage feeds an F–R–H double–shaft pug mill where sufficient water to achieve plasticity is added, as well as minor amounts of Lignosol® and barium carbonate.

Plugs for flowerpot production are extruded by an F–R–H Hummer, and these are individually pressed into plots from 4 to 30 cm in diameter. A flowerpot press consists of a revolving chuck that is pressed into a mould containing a clay plug of suitable size. Six rotating ram presses are available for different sizes and styles. They include two Foster presses, two Baird and two Pollard, all acquired from the Foster Pottery Company after Foster ceased production in the early 1970s.

Filter, structural and partition tiles are extruded by an F–R–H type WJ vacuum extruder. Several automatic cutters are available to cut the extruded clay stream, and the green ware are manually hacked onto drying cars.

Drying is accomplished in a tunnel dryer and a room dryer, each containing 16 tracks with a combined capacity for 385 cars. Drying takes about 48 hours at 98°C, waste heat from the kilns providing about one–third of the drying and direct natural gas heating providing the remaining two–thirds.

There are 10 beehive kilns of about 10 m in diameter. They are gas–fired to peak temperatures of about 1040°C and are turned over on cycles of 9 to 10 days. Average kiln capacity is 90 tonnes. Fuel consumption for drying and firing accounted for about 37 percent of operating costs in 1985, about the same as the costs of labour.

Flowerpot sales are mostly to greenhouses in the Toronto–Hamilton–Niagara area. Filter tiles are sold throughout North America, including Mexico.

TECHNICAL ASPECTS AND COMPETING MATERIALS

There are no technical standards that apply to the making of flowerpots. In Ontario, clay flowerpots were originally made from a red plastic clay of almost stoneware quality that was derived from eroding Queenston Shale in the Burlington and Hamilton areas. With the final depletion of these small deposits, other surface clays and shales have been substituted with varying success, but domestic producers have had trouble matching the quality of imports from the U.S.A., Germany and Italy. Both clay quality and old machinery are at fault.

Good plasticity and a sufficiently long firing range are desirable qualities in the clay raw material, to ensure smooth clay pot surfaces free from cracks, checks and warpage. Moderately high porosity and absorption characteristics are necessary for optimum development of plant root systems. Pot bases must be flat and the drainage holes smooth. Large scale greenhouse operations require these physical characteristics to be constant from shipment to shipment; particularly porosity and absorption, where automatic watering systems and humidity controls have been pre–set based on previous experience.

Clay competes with plastic, peat and fibre (papier mâché) flowerpots. All are cheaper, lighter, non–abrasive, and more easily stored and handled. Plastic flowerpots are less easily broken than clay pots and about half the price of those made in On-

tario. However, their lack of porosity inhibits optimum root development, and plastic is generally less attractive to the retail consumer. A plant sold in a clay pot will attract a substantially better price than one in a plastic pot.

Nevertheless, growers dealing in large numbers of pots have tended to favour plastic in an attempt to reduce costs. Conversely, retail consumers tend to show preference for clay pots for display purposes, particularly in the larger pot sizes.

Kord Products Limited is a major producer of plastic flowerpots at its Brampton plant. Although fibre pots have the advantage of being biodegradable (as are also peat pots, which Kord does not make), the value of plastic pot production is about three times that for fibre pots. Biodegradable pots can be used for starting seedlings in the greenhouse, then planting them in the ground with their pot to avoid the shock of transplanting.

Large, highly automated plants in the U.S.A, Germany and Italy are the source of most Ontario imports of clay flowerpots. Imports represent about three–quarters of the Canadian market for clay pots and are generally superior in quality. In spite of costing 30 to 50 percent more than Ontario pots, they are preferred by the retail market.

FILTER TILE

Filter tiles are used in the bottom of porous bed filters in water treatment applications. These applications may include filtering water for municipal consumption, filtering municipal sewage before discharge and filtering of industrial waste streams. Potential applications also extend to their use in biological reactors or digestors.

Filter tiles are rectangular units containing interior channels through which filtered water, entering via apertures in the tiles' upper surface, can be drained away. Depending on the channel design, backwash water, or both air and water for backwashing, is pumped into these channels and discharged through the surface orifices for scouring of the filter media.

Vitrified clay sees competition from fibreglass and plastics for the filter tile market. Clay has advantages over these products in its superior resistance to chemical (acid) attack and abrasive wear. Also clay is a relatively inexpensive material which when fired exhibits more structural stability than the other two materials. It, however, has the disadvantage that the tile produced are much heavier than those of fibreglass or plastic, as much as 40 kg compared to 7 kg for a plastic underdrain. Shipping costs are therefore a major contributor to the total installed cost of the system.

Clay filter tiles are produced by extruding and firing. The finished tile are usually 28 by 25–35 cm in cross section and 60 cm in length. The walls of the tile are made thick in order to meet the physical requirements of the vitrified clay filter block specifications. As listed in the ASTM standard C159 exterior walls must be at least 9/16 inch (1.4 cm) thick, interior walls at least 1/2 inch (1.2 cm). The tile must meet minimum compressive strength requirements of 450 psi (3 MPa) and have a maximum boiling absorption of 6 weight percent. Customers typically request more stringent specifications including a minimum internal rupture pressure of 25 psi (170 kPa).

PRODUCTION, CONSUMPTION AND IMPORTS

Canadian consumption of clay flowerpots is about 7 million annually. About 20 percent of these are produced in Ontario by Halton Ceramics Limited. The rest are imported from the U.S.A., Germany, Italy and Mexico. Three–quarters of the market is for pots of standard type in sizes less than 25 cm in diameter. The Canadian market is concentrated in the east, particularly in the Toronto–Hamilton–Niagara areas.

More than 90 percent of potted plants in Ontario are sold in plastic pots. The Canadian market for plastic flowerpots is valued at about four times that of clay pots. Plastic flowerpots sell for about half the price of clay pots domestically made, and one–third to one–quarter the price of U.S.A. and German clay pot imports.

The most important foreign source of clay flowerpots for the Ontario market is F. W. Ritter and Sons Inc. of Rockwood, Michigan, the largest of four U.S. producers of any size. Their annual sales are in excess of U.S. $5 million, about 5 percent of which are exported to Ontario. Their modern automated plant produces pots of excellent quality which sell for about 50 percent more than Ontario flowerpots. They are imported by a few distributors mainly for the retail market.

Germany and Italy are the other principal sources of clay flowerpot imports. German pots are of especially high quality and are distributed mainly to retail markets. Italian pots are sold to both grower and retail consumers.

Transportation is a major cost for clay flowerpots and a source of significant breakage. Pots must be shipped in corrugated containers with dividers and inserts.

Major Ontario importers of clay flowerpots are Rosedale Imports & Manufacturing Limited of Toronto, and Robinson Clay Products Company of Canada Limited, Concord. Rosedale imports mainly Italian flowerpots for distribution to growers and retailers in Ontario. Robinson imports pots from Italy, Germany and the U.S.A. primarily for distribution to retailers. Large growers and retailers also import directly for their own consumption. Retail sales are mainly through garden centres and department and hardware stores.

There are no statistics for clay filtration tiles. The market is small and widely dispersed. Halton Ceramics Limited is one of three producers in North America and the only one in Canada. Halton sells its product mostly in the U.S.A. and Mexico.

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Chapter 16 — Miscellaneous Clay Applications

INTRODUCTION

In addition to the major uses for clay raw materials, clay and shale are also used in a wide variety of smaller volume applications. Among these are absorbants (such as cat litter), fillers, oil well drilling fluids, grinding media and catalyst bed supports. Each of these applications will be briefly discussed, including a basic analysis of the potential for use of Ontario clay deposits in their associated manufacturing processes.

ABSORBANTS

The potential of a particular clay for use in absorbant applications, such as cat litter, depends on its capacity to absorb gases and liquids. In general, high absorbancy clays are classified in the smectite group and do not have well defined crystalline structures, i.e., they are mixed order clays. This group includes montmorillonite, attapulgite and Fullers earth.

In principle, virtually any clay could be used, from a materials handling, processing and forming standpoint, in cat litter production. Furthermore, even if the clay is not suitable, from an absorption standpoint, additional process steps, such as heat treatment or foaming, may be used to improve the absorbancy properties of a particular clay.

In general, clay deposits in Ontario are not suitable for processing into absorbants unless extra processing is performed. In most cases, both the technical and economic feasibility of performing this extra processing are not known. However, one example now exists. A novel process for producing a clay absorbant for use as cat litter from Ontario clay has recently been developed. Currently, this information is proprietary and not available for publication.

In conclusion, the clay raw materials of Ontario can not readily be processed into absorbants, the problem being the performance of the finished product. Although potential exists for this application, the technology development is a difficult task and would involve extra processing to achieve adequate absorbancy.

FILLERS

In recent years, use of clays as fillers and extenders has been increasing. Such applications make use of various clay properties such as platey crystal structure, natural binding action, high reflectivity and opacifying properties. Clays may be used in either their natural "as is" state or in a harder, more abrasive calcined state.

The most important clay property, when considering filler applications, is colour. Any filler or extender should be of a neutral colour and readily compatible with standard pigmenting procedures. Thus, highly coloured clays are unacceptable, and only the white raw materials (kaolin or china clay) find wide use. Occasionally, some of the grey and light brown clays also find application in products where colour is not considered to be critical.

Kaolin clay has major applications in many manufacturing industries. The function of kaolin in these products is given in Table 16.1.

Currently, no Ontario clays are used as fillers in commercial applications. Kaolin clays are currently imported (~300,000 tonnes annually) into Canada from Europe and the U.S.A. for the industries that need them. The kaolin deposits of the James Bay Lowlands have potential for use in filler applications, but because of their remoteness, they have not yet been exploited. Furthermore, some beneficiation of the clay to upgrade it to the quality of currently imported products would be required. More details are given in Chapter 3 of this report.

PETROCHEMICAL APPLICATIONS

The primary use of clay minerals in the petrochemical industry is in the formulation of drilling muds or fluids. The clays which find use in these applications are sodium bentonite, attapulgite and sepiolite. The rheological properties of these clays (the latter two in saline media) are the most important in determining suitability for use in these applications. The clay functions by increasing the viscosity of the mud such that drill cuttings are suspended and subsequently removed.

No Ontario clays are currently being used in drilling fluids. Although some Western Canadian deposits are being employed domestically, the large majority is imported. The clays of Ontario are not suitable for use in this application because they are not the right type or quality.

Another petrochemical application for clays is artificial fracture sands. In this application, the fired ceramic aggregates must have suitable size, shape, solubility and strength as specified by the American

TABLE 16.1 USE OF KAOLIN CLAY IN FILLER APPLICATIONS.

Industry	Function	Remarks
Paper	Increases opacity Improved surface	Minimum brightness value - 90%
Paint	Extender Improved rheology Increases opacity	
Rubber	Improved abrasion resistance Improved strength	Amino silane modified kaolin
Plastics	High electrical resistance in cable insulation	Calcined clay Other applications not well developed
Agriculture	Binders, extenders and diluents in fertilizers, feed and pesticides	Prevents particle agglomeration
Chemicals/ Pharmaceuticals	Binder/carrier for active ingredients	

Petroleum Institute (API RP 56). Competing materials for this application are silica sand, resin coated sand and sintered bauxite aggregates. Currently, no Ontario clays are used in this application. Their potential for use has not been investigated and is unknown.

CATALYST BED SUPPORTS/GRINDING MEDIA

A potential use for clay minerals is in the formation of a sintered product to be used as ceramic catalyst bed supports or as a grinding medium. These materials are used, in the shape of cylinders, saddles or spheres, as packing media to support finer grained catalysts or in grinding mills to accelerate comminution. To be used in these applications, a fired clay must have the following properties:

- high resistance to attrition,
- high resistance to thermal shock,
- chemical inertness,
- catalytic inactivity,
- low porosity,
- high crushing strength.

Although the catalyst bed support market is important in the petrochemical industry, sales are limited due to the extended lifetime of the product. A limited market also exists in the case of grinding media. In general, these products are considered to be low volume, high performance applications and Ontario clays are not considered to be suitable.